CONDITIONS IN IRON FOUNDRIES

First Report of the
Joint Standing Committee

LONDON
HER MAJESTY'S STATIONERY OFFICE
1956

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REPORT ON CONDITIONS IN IRON FOUNDRIES

To Sir George P. Barnett,

Her Majesty's Chief Inspector of Factories.

Sir,

INTRODUCTION

General

1. The report of the Joint Advisory Committee on Conditions in Iron Foundries,[1]* whose Chairman was the late Mr. H. E. Chasteney, H.M. Chief Inspector of Factories, was published in 1947. Soon after the report was completed and signed, Mr. Chasteney was killed in a street accident. The report, commonly called the Garrett Report, owes much to Mr. Chasteney's wisdom and knowledge and we feel that his important contribution should not be forgotten.

2. Arising from a recommendation in paragraph 4 of the report, you appointed at the end of 1947 a Joint Standing Committee from both sides of the Industry, together with representatives of the Factory Department with the following terms of reference :

> "To keep under review conditions and development in the Iron Founding Industry affecting the health and safety and welfare of the workers ; to implement and continue the work of the 'Joint Advisory Committee on Conditions in Iron Foundries' and to act as a consultative body on matters which may be referred to it by H.M. Chief Inspector of Factories."

3. The committee held its first meeting under the chairmanship of Mr. H. A. Hepburn, H.M. Deputy Chief Inspector of Factories, on 4th December, 1947 and has continued to meet at regular intervals. Mr. Hepburn remained chairman until his retirement in November, 1953 and the committee would like to record their great appreciation of Mr. Hepburn's services during his term of office. Mr. T. W. McCullough, H.M. Deputy Chief Inspector of Factories, a member of the original Joint Advisory Committee, succeeded Mr. Hepburn as chairman. Mr. H. Woods, H.M. Engineering Inspector of Factories resigned from the Committee in January, 1953 on his promotion to the rank of H.M. Deputy Superintending Inspector, having served continuously as Secretary of the Joint Advisory Committee and the Joint Standing committee since 1945.

The Committee is very grateful to Mr. Woods for his services and feel under an obligation to him for the technical and engineering skill which he so freely placed at our disposal. Mr. Woods was succeeded as secretary by Mr. W. B. Lawrie, H.M. Engineering Inspector of Factories, who had been assistant secretary of the original Committee. Owing to the increasing demands upon Mr. Lawrie's time the secretaryship has now been taken over by Mr. W. A. Attwood, H.M. Engineering Inspector of Factories. Mr. Lawrie has continued as a member of Committee and is mainly engaged upon the technical aspects of the work.

Mr. Adam Bennett M.B.E. of the National Union of Stove, Grate and General Metal Workers, a member of the original Joint Advisory Committee resigned from the committee in March, 1951 after having given three years of valuable service for which we are greatly indebted, and it was with deep regret that we heard, recently, of his death. Mr. J. Higham succeeded Mr. Bennett as a representative of his Union.

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*All numbered references are given in Appendix XVII on page 71.

Mr. J. D. Dobson, then representing the Ministry of Supply, joined the committee in February, 1948 and continued in that capacity until January, 1953. Early in 1954 Mr. J. Owen and Mr. J. D. Dobson, now of the Iron and Steel Board, both joined the committee, together with Mr. H. V. Shelton, representing the National Light Castings Ironfounders' Federation.

4. From the outset we accepted the recommendations of the Report of the Joint Advisory Committee as a foundation for our future work. This decision enabled us to concentrate on those problems which that Committee had indicated. Fresh problems have since emerged but the main effort of the committee has been directed to the discovery of methods by which the recommendations could be put into practice. The terms of appointment of the Joint Advisory Committee did not, however, require them to consider accident prevention in the industry. It is, of course, clear that many of the original recommendations, when implemented, would result in greater safety in iron foundries. Our own terms of reference, however, included specifically " the safety of the workers " so that, as soon as the more urgent research work was well in hand, we were able to turn our attention to this important problem.

As a committee, we have still much to do. We feel, however, that we should now submit to you a progress report on the work of the last seven years, even though the various industrial research and development projects have been published as completed. We think it desirable that the results of the research work undertaken by or on behalf of your committee should become known as widely as possible, and what is more important, put into practice in the foundry.

5. We began by discussing a list of problems extracted from the Report of the Joint Advisory Committee.[1] It was evident that solutions could only be found after detailed and prolonged study and that many aspects of the art and craft of founding would be involved before some of the questions posed in the earlier report could be answered. In consequence a Technical Sub-committee was formed, consisting of Mr. Colin Gresty (Chairman), Mr. J. Gardner, Mr. A. E. Pearce and Mr. W. B. Lawrie. In view of the diversity of the subject matter to be considered, this Technical Sub-committee was given powers to co-opt. These powers were used fully to ensure the best technical assistance, and we are indebted to those gentlemen who so freely placed their knowledge at the Sub-committee's disposal.

The first matter to which our Sub-committee turned its attention was the suppression of fumes from core binders. In consequence Mr. G. L. Harbach was co-opted to the Sub-Committee, as was Mr. W. B. Parkes of the British Cast Iron Research Association and, at a later stage, Dr. H. T. Angus of the same Association. It was decided later that the makers of binders should be represented and Mr. W. E. Aske, Mr. C. Wood and Mr. L. P. Wilkes of the Foundry Trades' Equipment and Supplies Association Ltd. were co-opted as representatives of that organisation.

Our Sub-committee also considered the question of fumes evolved from mould dryers in view of which Mr. F. Webster, Mr. R. G. Hanson and the late Mr. D. Newstead were co-opted as representatives of the Foundry Trades Equipment and Supplies Association Ltd.

At a later stage our Sub-committee discussed Knock-out ventilation and the Foundry Trades' Equipment and Supplies Association Ltd., was represented in this case by Mr. G. E. Lunt, Mr. W. M. Oddie and Mr. E. Partridge.

We have published three memoranda embodying the conclusions of our Sub-committee. The first entitled "Organic Bonding Materials for Foundry Cores and Moulds" reviewed the literature on gases, vapours and fumes evolved from core binders.[2] This was followed by a report[3] on "Practical Methods of Reducing the Amount of Fumes from Oil Bonded Cores," and another called "The Drying of Moulds by Portable Dryers."[4] These documents are discussed in the relevant sections of this report.

Medical Investigations

6. Since the publication of the Joint Advisory Committee report in 1947, the first comprehensive investigation into the pulmonary health risks of iron and steel foundry workers has been carried out by a team led by the medical member of our Committee, Dr. A. I. G. McLaughlin. The report of this investigation was published in book form in 1950 by H.M. Stationery Office.[5] A brief summary of the conclusions reached is as follows :

> "As regards iron foundries, clinical and x-ray examinations were made of 1,083 workers drawn from 15 foundries (in three of which steel as well as iron was handled) situated in the Midlands, the East Midlands, North West, North East and Southern England. In addition the records of cases of pulmonary diseases in the files of the Factory Department and the Silicosis and Asbestosis Medical Board (Dr. C. L. Sutherland, C.B.E., Chief Medical Officer) were analysed in 35 other iron foundries. Pathological examinations were made by Drs. H. E. Harding and S. Roodhouse Gloyne of the lungs of 14 iron foundry workers of varying categories. Detailed and thorough dust estimations were carried out by Mr. K. L. Goodall of the Factory Department in a large iron foundry both before and after improved dust control methods had been instituted.
>
> "Until 1943 the known cases of pneumoconiosis in iron foundry workers were few, and indeed until after the publication of the results of this investigation they were excluded from the provisions of the compensation schemes for silicosis under the Workmen's Compensation Acts. The difficulty of bringing them into the scheme was partly due to the fact that hitherto the classical silicotic nodule had dominated the study of the pathology of the industrial diseases of the lungs. Any case in which classical silicotic nodules were not found could not be diagnosed as silicosis and hence was not eligible for compensation. The pathological studies in this investigation showed that the main lesion found in the lungs of iron foundry workers (particularly iron fettlers or dressers) was another type of nodule with a linear and radial pattern as opposed to the whorled arrangement of fibres in the classical silicotic nodule. To this type of lesion Harding, Gloyne and McLaughlin applied the term "mixed dust pneumoconiosis" or "mixed dust fibrosis". Similar nodules were found in other groups of workers such as boiler scalers, graphite workers and coal miners who had also been exposed to a mixed dust containing a comparatively low proportion of free silica. The mixed dust pneumoconiosis nodule is, in fact, a modified silicotic nodule and is clearly caused by the inhalation of a siliceous dust. The condition of mixed dust pneumoconiosis (or modified silicosis) is, in the long run, as disabling and lethal as is classical silicosis which occurs in trades in which there is exposure to dust with a higher proportion of free silica. The establishment of this fact was one of the most important findings of the investigation because it enabled iron foundry workers to be brought within the scope of the compensation schemes and emphasised the need for more intensive efforts to control the dust in iron foundries.
>
> "The results of the field investigation were examined statistically in great detail by Dr. E. A. Cheeseman and important conclusions drawn about the incidence of pulmonary disease in the various categories of iron foundry workers. In general, it was found that the incidence of pulmonary disease was less in iron foundries than it was in steel foundries. For instance 16 per cent, of all steel foundry workers showed evidence of moderate x-ray abnormality (reticulation) whereas

only 6 per cent. of iron foundry workers had a similar abnormal x-ray appearance. Again, 3 per cent. of the steel foundry workers had severe x-ray changes (nodulation and/or massive shadows) as opposed to 1 per cent. of the iron foundry workers.

" Concerning the various categories of workers in iron foundries the following conclusions were made.

"*Shotblasters*

There is a risk of the onset of silicosis with or without tuberculosis to shotblasters. Statistical analysis shows that the risk is rather less in the blasting of iron castings than of steel castings. Cases of silicosis, though fewer in number, continue to occur amongst shotblasters, and men who previously worked as sandblasters in spite of stringent regulations requiring dust control measures. (The use of sand as a blasting material has been prohibited since 1949).

" *Dressers or Fettlers of Iron Castings*

Iron dressers or fettlers are exposed to the inhalation of dust which in some cases causes classical silicosis, but more often produces a modified silicosis (or mixed dust pneumoconiosis). The pneumoconioses of iron dressers and other groups of iron foundry workers may be accompanied by tuberculosis or pneumonia, either of which conditions may be the immediate cause of death. The incidence of the pneumoconioses and their corresponding x-ray shadows is lower in iron dressers than in steel dressers. The three probable reasons for the lower incidence are (i) the lower casting temperature of iron which produces less "burning-on" of the moulding sand on the casting ; (ii) the pneumatic tool is less often used on iron castings than on steel castings and (iii) the moulding mixtures for iron contain less free silica than is the case in steel moulding.

" *Iron Moulders*

A proportion of these workers also develops well marked silicosis and mixed dust pneumoconioses. It is likely that the free use of silica parting powders (now prohibited by the Foundries (Parting Materials) Special Regulations 1950) has been mainly responsible for cases of silicosis amongst iron moulders. Statistical analysis showed that the incidence of abnormal x-ray appearances in iron moulders is slightly less than it is in iron dressers. But in foundries where small castings were being made the reverse was the case. The size of the casting appears to have an important bearing on the silicosis risk to iron moulders because the larger the casting the less often are the moulders exposed to dust clouds from the knockout or parting powders.

" *Coremakers and Coreshop Workers*

Coremakers and workers in the coreshop are exposed to a minimal risk of silicosis and mixed dust pneumoconiosis if they work in a room separated from other foundry processes.

"*Knockout Workers*

Many moulders do their own knockout and it was not possible to find a satisfactory group which was only engaged on the knockout. Such figures as are available in other countries show that the risk of silicosis and other forms of pneumoconiosis though present, is rather lower than it is in the case of dressers.

"*Pattern Shop Workers*

These workers occasionally show mild x-ray abnormalities, but not of ill-health or disability. They are mainly exposed to the inhalation of wood dust, some types of which may irritate the respiratory passages. Without pathological evidence it is not possible to be certain about the cause of the x-ray shadows.

"*Furnacemen*

Furnace workers, including casters, ladlemen, pourers, cupola attendants and annealers may develop comparatively mild abnormal x-ray appearances due to the inhalation of dust. These abnormal changes are more pronounced in steel furnacemen than in those working in iron or mixed iron and steel foundries. It is probable that most of the abnormal x-ray changes are due to siderosis (a benign pneumoconiosis) because they are mainly exposed to the inhalation of iron oxide fume. The possibility of mixed dust pneumoconiosis or even silicosis cannot be ruled out, because there is also some exposure to the dust of free silica present in the general atmosphere of the foundry.

"*Crane Drivers*

These workers also show abnormal x-ray changes which are more marked in steel than in iron foundry workers. Again, the changes are more advanced in crane drivers in the dressing shop than in the moulding shop. Some of the abnormalities are probably due to siderosis (especially in the moulding shop) but in the dressing shop there is a greater possibility of the onset of silicosis or of mixed dust pneumoconiosis. It was shown that in many instances the dust concentrations were greater at the level of the crane track than on the floor of the shop.

"*Welders*

Welders are rarely employed in iron foundries but where they are they may develop siderosis as a rssult of the inhalation of iron oxide fume. The x-ray appearance closely resemble those of silicosis, but siderosis is not a disabling condition. But when welding, oxyacetylene flame cutting or burning is carried on in a dressing shop, in which the dust of free silica is present, the welders are exposed to the risk of silicosis and/or mixed dust pneumoconiosis.

"*Sandmixers*

These workers have a fairly low incidence of abnormal x-ray appearances, but there is a risk of the onset of silicosis the gravity of which depends on the proportion of used sand (and occasionally silica flour) in the moulding mixture and on the efficiency of dust control methods, and, of course, on the length of exposure to the dust.

"*Ancillary Workers*

This group contains labourers, slingers, truck drivers and internal despatch men, and is a homogeneous one in that they are exposed to the inhalation of dust in the general atmosphere of the shop, as opposed to other groups such as blasters, dressers and welders who are exposed to high concentrations of various types of dust. The group in iron foundries shows a fairly low incidence of the milder degrees of x-ray abnormality and no case of actual lung disease or disability was found. The moulding shop labourers show less abnormality than the dressing shop labourers. It is possible that the abnormal x-ray changes found might represent the early stages of silicosis, mixed dust pneumoconiosis or siderosis but no pathological evidence is available to confirm or disprove this theory.

"*Maintenance Workers*

In general maintenance workers are comparable with the previous group in that there is exposure to the dust of the general atmosphere of the shops and the incidence of x-ray abnormality is low. In some instances there is exposure to high concentrations of siliceous dust, and it is possible for a maintenance worker on occasion to contract silicosis after many years exposure.

"*Furnace Reliners*

It is found that workers engaged in the dismantling, relining and rebuilding of melting furnaces are exposed to a serious risk of silicosis, particularly if they are engaged whole-time on the job.

"*Young Foundry Workers*

Young workers in all foundry occupations (except pattern making) may develop mild x-ray abnormalities after comparatively short exposures. No disability is associated with these changes which might be due to congestion set up by the "foreign body" reaction of the lungs to dust ; this reaction is likely to be more active in young workers. Again it may well be that the lungs of young workers are more susceptible to the action of free silica.

"*Tuberculosis*

The incidence of tuberculosis in this group of foundry workers was found to be no higher than that in the general population. But in those who died from silicosis, just over half had tuberculosis as well. Tuberculosis is a well-known complication of silicosis.

"*Cancer*

Though some investigators have found a higher incidence of cancer of various sites of the body in foundry workers, no cases were found in the general clinical and x-ray survey of this group. In the pathological investigation of 64 cases, drawn from all types of foundries, 3 cases of cancer of the lung were discovered.

" It might be added that, though surveys of foundry workers have been made in various countries since 1931, this was the first to include observations on the pathology of the lungs. The findings of the whole investigation are therefore the more valuable. There is always room for argument about the interpretation of x-ray appearances, but little about the pathological and histological features. A further point which emerged was that it was possible for men to work for long years in silicosis-producing occupations and to die from causes other than silicosis."

As Dr. McLaughlin pointed out in his Malcolm Morris Lecture for 1952,[6] individuals vary greatly in their capacity to deal with dusts, and of two men who have been working at the same job for the same length of time, one may get a disease of the lungs and the other may be unaffected. " This one reason " he says, " why I am not greatly impressed by the validity of what are known as maximum allowable concentrations of dusts (M.A.C.) of which lists have been drawn up in various countries. The M.A.C's. seem to be based on the assumption that man is a standardised machine, which clearly he is not."

7. *Activities of Employers*

The deliberations of our Sub-committee soon indicated that much research work would be necessary if answers were to be found to the many questions raised. We therefore approached the British Cast Iron Research Association and the Council of Ironfoundry Associations in order to make the necessary arrangements for this work. As a result the Foundry Atmospheres Committee of the British Cast Iron Research Association was established with our member, Mr. Colin Gresty, as chairman. This Committee is responsible for much of the research work which led to the development of a new system of exhaust ventilation on the stand grinder, as well as analyses of fumes from mould dryers. Both subjects are discussed in more detail below (pp. 12, 18, 19, 20).

The Foundry Atmospheres Committee sponsored in September, 1951, a three-day conference at Ashorne Hill at which a full discussion took place on heating, lighting and ventilation in iron foundries. The proceedings of this conference were published by the British Cast Iron Research Association.[7] The Foundry Atmospheres Committee concluded that the control of dust at the knockout was a particularly difficult problem and set up a ' knockout panel ' which brought together users and designers of knockout equipment and ventilating engineers. A further conference on ventilation and dust control was similarly sponsored at Harrogate in April 1955 at which the work of both the Foundry Atmospheres Committee and the Knockout Panel was published.[38]

In 1953 the Council of Ironfoundry Associations set up a Safety Committee so that the question of accident prevention could be fully investigated by them. This Committee has been supplied with statistical analyses, prepared by our Secretary, of reported accidents for use in connection with their investigation. In March, 1954 the Council of Ironfoundry Associations arranged a two-day conference of employers at Ashorne Hill to stimulate interest in the subject.[8] You yourself took a prominent part in the discussions together with other members of your Department and there was a valuable interchange of views. An interesting feature of this conference was an exhibition of safety equipment from the then Safety, Health and Welfare Museum, arranged by Mr. J. O. Peacock.

8. *Activities of Trade Unions*

The Amalgamated Union of Foundry Workers has naturally been closely interested in conditions in iron foundries and we are fortunate in having as one of our members Mr. J. Gardner, the General Secretary of that Union. Mr. Gardner has kept his members fully informed about our work. He has also invited members of the Factory Department to address Annual Delegate Meetings of his Union about safety, health and welfare matters in foundries.

We are also indebted to others of our members—Mr. J. H. Wigglesworth of the Iron Steel and Metal Dressers' Trade Society and Mr. J. Higham of the National Union of Stove, Grate and General Metal Workers—for the assistance they have given in keeping their members informed of our work. Mr. Wigglesworth and Mr. Higham, like Mr. Gardner, have invited speakers from the Factory Department to the National Conferences of their Unions so that their members could have up-to-date information, and the opportunity of discussing it.

9. *Official Activities*

An official party consisting of Mr. H. A. Hepburn, Dr. A. I. G. McLaughlin and Mr. W. B. Lawrie visited Scandinavia in October, 1950 to study foundry conditions and on their return furnished us with a valuable report which described, among other things, new methods of foundry ventilation.

10. In the early post-war years prior to 1953, the Committee maintained close contact with the Ministry of Supply in an effort to assist all parties in the difficult decisions then involved in granting building licences. This activity ceased on a resumption of more normal conditions and the almost total abolition of control of building licences.

11. The following new codes of regulations applying to foundries have been issued dealing with both iron and steel foundries :—

The Factories (Cleanliness of Walls and Ceilings) (Amendment) Order, 1948
The Blasting (Castings and Other Articles) Special Regulations 1949
Grinding of Metals (Miscellaneous Industries) (Amendment) Regulations 1950
The Foundries (Parting Materials) Special Regulations, 1950
The Iron and Steel Foundries Regulations, 1953.

We have discussed these codes, as they have appeared, in so far as they have affected our terms of reference, and where necessary have modified the applied research projects which we had in hand.

12. *Improvements in the Industry*

It is impossible to measure precisely the changes that have been made over the whole industry since the Garrett Report was published, but we think that some general indication can with advantage be given.

From 1st October, 1946, when the former Iron and Steel Board was instituted, until 31st December, 1953, the Ministry of Supply approved 269 applications for licences to carry out building and civil engineering work primarily to improve working conditions in iron foundries, and to provide lavatories, washing facilities (including baths) and canteens. The total estimated expenditure on these schemes was £1,259,276 and the total number of schemes approved year by year was as follows :—

Year	*No. of Schemes*	*Estimated Expenditure* £
1946 (2 months)	7	6,210
1947	22	171,030
1948	44	216,205
1949	37	206,881
1950	40	215,023
1951	57	241,224
1952	52	128,462
1953	10	74,241
	269	£1,259,276

In addition to these schemes the Ministry of Supply approved during the same period, 1,476 building licence applications for the erection of new iron foundries and for extensions and repairs to existing iron foundries. This involved a total expenditure of £17,289, 943 including the cost of plant and equipment. Many of these schemes incorporated amenities and improvements in working conditions, and it is estimated that £1,750,000 (or about 10% of the total expenditure) represents the cost of those amenities and improvements.

On this basis the total estimated expenditure on amenities and improvements in working conditions amounted to about £3,000,000 during the period 1st October, 1946 to 31st December, 1953. This is not the full total, which is not known, but we think it right to give some indication of the great measure of voluntary support which was accorded by the industry to the recommendations of the committees dealing with iron and steel foundries before the introduction of the Iron and Steel Foundries Regulations, part of which became operative on the 1st January, 1954.

DUST

DUST DETERMINATIONS

13. *General Considerations*

Work on dust determinations was begun as a result of the findings of the Joint Advisory Committee on Conditions in Iron Foundries and of the medical investigation to which we have already referred. No experimental work had been done by the Joint Advisory Committee though consideration of existing literature and knowledge had led it to the conclusion that[1] "unfortunately existing and reliable methods of sampling, counting and analysing dust concentrations call for expert knowledge and are laborious and involve very considerable expenditure of time." It was reported that "it would therefore be impracticable at present to undertake this work on a large scale in foundries generally." The committee also indicated that "there are no reliable existing standards by which conditions could be assessed."[1] In consequence it commented on the desirability of developing "some quick and accurate method of dust estimation in foundries."[1] This matter was, at the time, being considered by the Dust Hazard Panel of the Industrial Health Advisory Committee of the Medical Research Council. The Joint Advisory Committee, however, had also suggested that the "possibility should be explored of using some quick and simple method which would enable rough comparisons to be made between................ conditions in different foundries with a view to arriving at some empirical standard based on the lowest dust concentration found in practice."[1]

It was agreed that a quick and simple method of dust estimation was an urgent necessity to facilitate research on dust control methods. It was decided that *the real need was to reduce the amount of dust in foundries*, and that while early work would have to be done on dust determination methods, this work should not be looked upon as an object in itself but rather as a means to an end.

In consequence a member of the committee, Mr. W. B. Lawrie, developed a rapid estimation method during 1948 and the work was published in September of that year.[9] In addition, the method was described in Appendix 2 of the Second Report of the Dust in Steel Foundries Committee (1951).[10, 11]

14. The Moulding Materials Committee of the British Iron and Steel Research Association adopted the method as a standard technique and in co-operation with the British Steel Founders' Association a general survey of conditions in steel foundries was begun and some of the results were published in 1951.[12] Some dust estimations were also done in iron foundries and the experience gained in using the method showed that it was accurate enough for the purpose for which it had been devised.[13] Following the suggestion made in the original work,[9, 10] the dust concentrations were reported in group numbers instead of particles per cubic centimetre. Later, in a statistical survey of two environmental studies, the use of group numbers was compared with the older method of reporting dust concentrations. This statistical work[14] resulted in the conclusion that "analysis of counts expressed in group numbers, in which the dust concentrations between adjacent steps are arranged in geometrical progression is probably the more satisfactory procedure for the establishment of dust levels."

The method has now been used extensively in iron foundries, both in an effort to obtain figures indicating dust[12, 14, 15] levels and as a rapid check on progress in the developing of particular dust control systems for specific purposes.[20, 21, 22, 23, 24]

15. *Dust Observation and Photography*

It is generally considered that dust particles of less than 10 microns * in diameter are the most dangerous and it is well known that these particles are invisible in ordinary lighting conditions. It was only by means of sampling instruments, therefore, that the presence of dangerous dust clouds could be detected so it was concluded that great benefits would accrue if a method could be devised by means of which moving clouds of very fine dust could be observed. The necessity for such a method was underlined by the results of the new technique of estimation which had shown that the provision of local exhaust ventilation for certain grinding wheels had not reduced the average dust concentration in the dangerous size range.[16] It was not known at this time whether such a result was due to efficient local exhaust systems of ventilation extracting average dusty air from all over the rooms in which they operated or whether it was due to the inefficiency of these systems. A further unexpected indication from the general surveys was that the dust samples taken at the breathing level of pneumatic chisel operators appeared to fall roughly into two groups. One of these groups showed high concentrations which had been anticipated because the occupation has a well known risk of silicosis, while the other group showed low dust concentrations, which had not been anticipated. It appeared that these results might have been caused by the fact that the instruments sometimes sampled the dust cloud, and sometimes sampled much cleaner air which was surrounding the main cloud. It thus became apparent that the reason for these results could be most easily ascertained if the dust clouds could be made visible to the naked eye.

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* 1 micron $= \frac{1}{1{,}000}$ millimetre $\bumpeq \frac{1}{25{,}000}$ inch

The possibility that the path of dust clouds could be best studied by taking moving pictures of them in a beam of strong light was developed by a member of our Committee, Mr. W. B. Lawrie, who, with the assistance of the staff of the Photographic and Reproduction Branch of the Air Ministry carried out field experiments. The object was not so much the measurement of dust concentrations but rather to see the direction taken by the dust clouds. It was found in practice that the dust clouds did in fact become visible and the method formed a means of observing the aero-dynamics of dust control systems.

16. When a powerful beam of light is passed through a suspension of a finely divided solid in a gas or liquid the resultant scattered light makes the path of the beam easily visible, particularly if the experiment is done in darkness with the beam itself providing the only light source. It was found in the early stages of the work that dust clouds which were completely invisible in ordinary light could be easily seen in the beam of a 5,000 watt lamp if the cloud were observed at an angle of about 10° from the axis of the beam. It was also found that these clouds could be recorded on a 35 m.m. cinematograph film if the camera was focussed on the cloud, looking up into the beam, care being taken to avoid glare in the camera.

17. This work was published [17] in 1951 since when it has been successfully applied to a series of development projects. It has been shown that the very fine and dangerous dust can be photographed ; [20 21] and that the method can be used under ordinary foundry conditions. The method has proved itself to be a valuable practical instrument and we have noted with interest the results of an effort to determine the lowest particle size and dust cloud concentration that can be seen. This work is still proceeding and the results will be made available in due course.

The mere observation of dust has been of great assistance in engineering developments, and the photography has provided still further information because the path of a rapidly moving dust cloud can be examined in detail and at leisure. High speed cinematography has been used in certain cases to provide slow motion pictures, although for most of the work normal camera speeds have proved sufficient. The standard photographic method at once showed[17] that the dust cloud from a pneumatic chisel left the chisel point in the form of a plume, which moved along the work a very short distance before turning upwards to follow the line of the chisel and rise up the operator's arm to his face. It was apparent that the divergent results obtained during dust sampling on the pneumatic chisel had been caused by the fact that the cloud was hitherto invisible. This had meant that it was entirely fortuitous whether the sampling instrument was in the cloud or only near to it. Plate 1 shows the first photograph in which this effect was observed.[17]

18. On applying the same technique to work on a pedestal grinder, photography of the dust cloud resulting from grinding, showed that the conventional local exhaust system was by no means as efficient as had been supposed. Plate 2 a " still," taken from an early film,[17] is the first photograph which showed that dust is ejected from the opening between the top of the guard and the wheel, even when a conventional local exhaust ventilation system is fitted and operating. Plate 3, similarly taken from the first film, shows the dust distribution observed when a portable abrasive wheel was used to grind a flat surface in still air.[17] This photograph indicated that the dust of small size range did not follow the line of the sparks but flowed over the wheel top and appeared as a vortex between the wheel and the operator's face. The work indicated that dust control systems which had been arranged to collect large particles such as sparks failed to collect dust of the dangerous size range.

DUST SUPPRESSION

19. *General*

Before proceeding to a discussion of the research and development work we should like to make some remarks about the terms we use. Included in the term "dust suppression" are all the methods by which the atmospheric dust concentration can be reduced. These methods fall into three general groups :— (i) elimination of the dust ; (ii) elimination of the dangerous fraction of the dust ; (iii) control of the dust.

20. (i) *The Elimination of Dust*

The elimination of dust must always be the primary object. This is a counsel of perfection and even to approach it will make great demands on the technical ability of foundrymen. Any future change in practice which results in the elimination of dust will improve the foundry without the necessity for dust control equipment. This in turn means a financial saving, more space on the foundry floor and less maintenance. It also means the best foundry, because dust control systems are not normally perfect in practice, and it is unlikely that dust, once it has been dispersed, will ever be completely controlled.

In the relevant section of this report we refer to methods by which the amount of fume from oil bonded sands can often be reduced and this is an example of the application of this principle of dust and fume suppression. It is hoped, therefore, that all foundrymen will constantly seek better working techniques in a deliberate and persistent effort to avoid the production of dust and even if only a fraction of the dust can be eliminated conditions will be improved and at the same time the load on the dust control equipment will be decreased. As a result, the ventilating engineer will have a simpler problem and may well be enabled to design a more efficient control unit.

21. (ii) *The Elimination of the Dangerous Fraction*

The second method of dealing with dust is to avoid the use of materials or processes which produce a dangerous dust cloud. This method may not result in a lessening of the dust cloud but it is always worth while to eliminate a dangerous fraction of the dust whether the concentration of the residual dust is reduced or not. One example of this approach is to be found in the Regulations which now prohibit the use of silica flour as a parting powder.[18] It is well known that the application of a parting powder results in a fairly dense airborne dust cloud. So long as silica flour was used this dust cloud was dangerous because it contained particles of free silica less than 10 microns in diameter. The substitution of a non-siliceous parting powder did not of course reduce the concentration of the airborne dust cloud, but it did eliminate the dangerous dust from this source. A further example of the method is seen in the prohibition of the use of free silica as an abrasive in certain blasting operations.[19]

22. (iii) *Dust Control*

Finally, there are various methods of dust control. These methods will often be the only practical ones available, and they will continue to serve over a wide field after every effort has been made to reduce the atmospheric dust cloud by the more positive techniques of dust elimination. In consequence your committee has devoted a considerable amount of time and effort in encouraging the improvement of existing methods of dust control and original work where there is no known method of control. Much has been done ; some success has been achieved, but there still remain many difficult problems which have not yet been solved.

DUST CONTROL BY LOCAL EXHAUST VENTILATION

23. *The Pedestal Grinder : The* 14" *Diameter Wheel*

One of the first observations made by the new illumination technique showed that the conventional system of local exhaust ventilation fitted to stand grinders was not successful. The observed effect can be seen in Plate 2. This early photograph was taken on a 24" diameter wheel, and it was then decided that the matter warranted a full investigation on different wheel sizes running at different peripheral speeds. The investigations which resulted from this decision were carried out by a member of the committee and a member of the staff of the British Cast Iron Research Association.[20] [21]

24. These workers began with a 14" diameter wheel running at a peripheral speed of 5,000 feet per minute, and developed a new system of local exhaust ventilation which became known as the "External System," because the exhaust was applied outside the wheel hood.[20] An account of this experimental work is given in Appendix I. The project showed that the effects observed in the first film, on a 24" diameter wheel, were also present on the smaller and slower wheel. It resulted in a new method of dust control which appeared to be much better than anything hitherto known.

25. *The* 24" *Diameter Wheel*

When the first project had been completed the Foundry Atmospheres Committee decided, and we agreed, that the results had been sufficiently promising to justify the extension of the work to a larger wheel. Accordingly the same workers studied the 24" diameter wheel,[21] which runs at a peripheral speed of 9,000 feet per minute. The experimental work is summarised in Appendix II. It will be seen that the external exhaust system was fitted as an addition to the existing conventional system, and that certain other modifications were made. This combined exhaust system gave excellent dust control on the prototype,[21] and at this stage we concurred with the conclusion of the Foundry Atmospheres Committee that enough is known about stand grinders to enable satisfactory local exhaust ventilation to be applied.

26. *The Portable Grinder*

Portable grinders are often used without any kind of dust control, with the result that heavy dust clouds are generated. Small work may be ground on a bench fitted with exhaust ventilation, but heavy work cannot be treated in this way, and some method of controlling the dust is essential. In view of these considerations a member of the committee, together with two members of a private firm, investigated the matter and devised a new system of dust control.[22] This is described in Appendix III (q.v.). The exhaust ventilation employs a low volume of air at a high velocity, and the unit for dust control is designed as an integral part of the machine.

27. *The Bench Grinder*

The work on the portable grinder represented a new approach to exhaust ventilation, relying as it did on vacua up to several inches of mercury, and using air volumes as low as 25 cubic feet per minute at velocities in the ducts of the order of 12,000 feet per minute. The investigators, after completing the prototype of the portable machine then proceeded to adapt the system to a bench grinder with a wheel 8 inches in diameter.[23] This was done in a effort to reduce the amount of air needed for local ventilation, because the extraction of such small volumes of air would not materially influence the heating system of a large building.

The results have already been published in detail[23] and are described in general terms in Appendix IV which also includes dust photographs and dust estimations.

28. *The Surface Grinder*

Some foundry dressing, *i.e.* cleaning of castings, is done by portable grinding machines in which the abrasive wheel is so mounted that the flat surface of the wheel grinds the metal. The wheel edge is not used for cutting in these machines which are known as portable surface grinders, or disc grinders. For many reasons this design of wheel has made dust control difficult. It appeared, however, that the new low volume high velocity method of exhaust ventilation might be suitable, and the problem was, therefore, investigated. A grinder[24] has now been produced in which the exhaust ventilation system is integrated with the machine. Dust photographs, dust estimations and a general description of the work appear in Appendix V.

29. *The Swing Frame Grinder*

Some early work on the swing frame grinder was done by the British Cast Iron Research Association, but in order to avoid duplication of effort it was agreed that the problem of dust control at this machine should be investigated by the British Steel Castings Research Association. This work has now been published[39] and is described in Appendix VI.

The British Cast Iron Research Association completed a survey on an exhaust booth for the swing grinder before relinquishing the project to the British Steel Castings Research Association, and this survey has now been published.[25]

The new low volume high velocity method has also been adapted to the swing frame grinder[24] and a description of this work appears in Appendix VII.

30. *The Pneumatic Chisel*

The application of exhaust ventilation to pneumatic chisels has proved a particularly difficult problem especially when those tools are being used on large castings which cannot be put on to benches. Recently a member of the committee, and two members of the staff of a private firm, have devised a new method of exhaust ventilation in which the ventilating air is applied at high vacuum, to a point close to the cutting edge of the chisel.[22] The fine dust may be extracted through a hollow chisel, or through a duct applied externally. The work was published in April, 1954[22] but a summary of the results which led to the prototype is given in Appendix VIII, together with dust photographs and dust estimations. The method has given promising results and development work is continuing.

31. *The Knock Out*

We include in the term " knock out " all methods of removing castings from the sand in which they were made. This means that the term covers a variety of operations performed in many ways in different foundries. There can be no doubt that the control of dust at knock out operations presents a series of difficult problems. The Joint Advisory Committee indicated the scope of the operation, and commented on some of the difficulties which are commonly met.[1] They also expressed the opinion that " proper control of dust and fume by local exhaust ventilation . . . . . can only be achieved by restricting the area over which the knock out is done." We are in substantial agreement with this view, though we cannot fail to appreciate the difficulties in transport which appear in certain foundries when an attempt is made to centralise the knock out operation.

It is also apparent that nothing can be done along these lines in pit moulding foundries, where the knock out process would have been completed by the time the casting had been lifted from the pit and moved to a central point.

32. The Foundry Atmospheres Committee have given much thought to the matter and the British Cast Iron Research Association who did experimental work on their behalf have now published the results of this work to date[40]. It was apparent from the start that there could be no easy solution to this complicated problem, and so the Foundry Atmospheres Committee set up a Technical Panel to consider the matter in detail, treating each type of knock out as a separate project. The Panel has considered the problem on a wide basis and a report on the whole subject has recently been published.[41]

33. *Mechanised Foundries*

It is normal for the knock out to be situated at one or more permanent positions in mechanised foundries, and we agree with the Joint Advisory Committee that local exhaust ventilation can and should be applied in these cases. The amount of dust and steam to be controlled at such a knock out point will be determined by many factors, *e.g.*, the temperature, the box size and the ratio of sand to metal in the box. The specification of the control system will, therefore, vary from foundry to foundry. The Technical Panel[41] concludes that dust control may be applied by (i) complete enclosure suitably exhausted (ii) side hoods with or without a positive air movement to direct the dust thereto (iii) down draught through the grid or (iv) a hood fitted over the top of the grid. The full paper is reprinted as Appendix IX.

We take the view that the best dust control will be attained only when a fully automatic and completely enclosed knock out has been designed. In this case a negative pressure inside the enclosure would suffice for dust control. We hope that designers of knock out plant and engineers will give this matter serious and urgent consideration.

34. *Heavy and Jobbing Foundries*

The control of dust during the removal of a heavy casting from a pit is a singularly intractable problem, and we know of only one practical attempt to solve it. This is in Sweden where underground exhaust ducts have been fitted to heavy moulding pits. The ducts are closed during pouring but can be opened when the casting is being removed from the pit. This method was mentioned in the British Cast Iron Research Association Conference in 1951.[7]

We have noticed with interest a successful attempt to replace pit moulding by box moulding and so avoiding the difficulties of dust control associated with pit moulding. This method is described in a paper published at the British Cast Iron Research Association's Conference at Harrogate in 1955.[42]

There is also in Sweden a totally enclosed heavy knock out grid. The enclosure is designed so that the roof and front can be retracted to enable a crane to place castings up to 60 tons in weight on the grid.

35. *Light Foundries*

The position in light foundries where boxes are cast in situ has not altered since the publication of the Report of the Joint Advisory Committee. We agree with that report both as to the desirability and the difficulty of conveying boxes to a central knock out point at which local exhaust ventilation could be applied.

Any appreciable future progress will probably only be practicable as a result of developments in foundry techniques.

DUST CONTROL BY WATER

36. *Water Sprays*

Many attempts have been made to control airborne dust by means of water, but it is still not a very satisfactory method. If a process can be done wet, or in solution or suspension there is no dust. But this is a method of dust elimination and not a dust control technique, and the two different methods of dealing with dust should not be confused. If, however, the process must be done dry, once an atmospheric dust cloud of the dangerous size range is allowed to develop it is almost impossible to bring it under control by means of water. We are informed that experimental work has been done in dressing shops where water was being blown into the air by means of atomizers. No differences in dust counts have been recorded whether the sprays were working or not. It has been said that the atmosphere was pleasanter with the sprays working, but this probably results from the fact that moist and dusty air may not be so unplesant as dry dusty air. It appears also that the humidification due to the water sprays should decrease the rate of evaporation from green sand in a foundry. In consequence less dust should be produced, although no experimental evidence has been adduced to support this suggestion.

37. *The Wet Portable Grinder*

(*a*) *Internal Water Feed*

The British Cast Iron Research Association has designed a portable grinder which can be worked wet.[26] The wheel is mounted on a hollow spindle through which water can be pumped. The water flows from the shaft into the wheel itself, and as the sides of the wheel are sealed it leaves the wheel at the cutting edge. In consequence the point of contact of the wheel with the work is constantly fed with water. Early dust estimations indicate, however, that the method does not give complete control of the fine dust produced when grinding but the performance of the machine with respect to different particle sizes has not yet been assessed.

(*b*) *External Water Feed*

The British Cast Iron Research Association has also adapted a portable grinder for wet working.[27] In this machine a single jet mounted on the edge of the wheel guard sprays water on to the wheel. Early dust estimations indicated dust leakage through the water, and the efficiency of the system with respect to the various particle sizes of dust has not yet been determined.

38. In view of the difficulties encountered in other applications of water it is apparent that the design of the above systems must be improved if they are to be accepted as a satisfactory solution to the problem.

DUST ELIMINATION BY WATER

39. *Moisture Content of Sand*

It is well known that a green sand does not appear to be dusty and it is quite clear that a good deal of dust is generated by dry sand. It seems therefore that a reduction in concentrations of airborne dust might result from any method by which sand could be kept moist. Obviously dry sand will appear in any foundry in certain conditions, but if the time during which it is dry could be reduced, or if the amount of dry sand could be reduced it seems reasonable to suppose that the dust would also be reduced. It has already been suggested that a very small amount of moisture would keep sand dust free[28] but this observation had only the simplest experimental basis.

The Foundry Atmospheres Committee decided therefore that it was desirable to estimate the amount of moisture which would suppress dust in sand, and the experimental work was done in the laboratories of the British Cast Iron Research Association.[29] Various kinds of sand were vibrated on a standard Sinex Sieve Shaker and dust countswere taken in controlled conditions. It was shown that the moisture contentat which dust evolution ceased was about one half of the working moisturecontent of the sand. Apart from the dust counts, the dust clouds were observed by the illumination method, and the figure of 45% was the point at which dust first became visible.

40. It appears from the whole of the work that any normal foundry sand which contained one third to one half its working moisture would be dust free for all practical purposes if the moisture were well distributed. It was observed during the experimental work that the addition of coal dust appeared to increase the amount of moisture required to suppress dust.

41. *The Wet Decoring Bar*

We have noted with great interest the work of the British Cast Iron Research Association where nozzles have been fitted to an ordinary bar in such a fashion that they deliver a cone of fine water spray around and along the bar.[30] This spray projects beyond the point of the bar, so that when it is used to de-core a casting the water wets the sand before it is disturbed by the bar. In consequence the damp sand appears to be dust free. This method, which is briefly described in Appendix X relies on the elimination of the dust by wetting the core sand before it is worked. It should be noted that this is a method of elimination rather than of dust control.

CUPOLA DUST

42. *Spark Arresters*

The design and efficiency of cupola spark arresters has been examined by the British Cast Iron Research Association. Although it may not be directly connected with conditions in iron foundries, the subject arose during the carbon monoxide determinations instigated by our Sub-Committee.[31 32] During this work attention was drawn to the cupola, and as part of the whole question, to the spark arrester. This led to a survey of various types of arresters.[31] It was concluded that "(1) the expansion—deflection type is inefficient, (2) A penthouse will suffice to keep adjacent roofs clean, (3) The cone baffle and water spray system appeared to be the best, but very elaborate and expensive equipment seems to be needed to get efficiencies over 70%."

So far as conditions inside the foundry are concerned a good spark arrester will help to keep the roof lights and gutters clear of dust.

The spark arrester may effect the amount of carbon monoxide which leaks from a cupola, and this aspect of the matter is discussed under the relevant heading in paragraph 3 of Appendix XI.

CARBON MONOXIDE

43. The Joint Advisory Committee did not directly discuss the amount of carbon monoxide that might be present in foundry atmospheres, but the sections on Open Fires, Ladle Drying and Heating, Mould Drying and Mould and Core Stoves clearly envisaged the danger. We therefore remitted the whole subject to our Sub-Committee, and our comments on it are based on their work. It may be true that there has been comparatively little trouble from this source in

existing foundries in this country, but it is also probably true that this immunity is accidentally conferred by unintended ventilation. We think, however, that the subject requires some attention in modern foundries which are housed in good buildings with the proper heating and controlled ventilation recommended in the report of the Joint Advisory Committee.[1]

44. *The Cupola*

More carbon monoxide is produced by the cupola than by any other source in the foundry, the stack fumes containing from 10—15% of this gas. Most of the carbon monoxide leaves the cupola at the top of the stack, but some may escape through the charging door. Many charging platforms are in the open air and this may account for the relative absence of gassing accidents. On the other hand the Joint Advisory Committee recommended that "Roof cover, as complete as possible, should be provided to protect men from the weather" adding the caution that "the arrangements should be such as to ensure that the ventilation is sufficient to prevent gas from collecting over the platform."

The presence of carbon monoxide in the foundry atmosphere around the cupola base was first reported in Sweden where the cold winter climate had necessitated buildings of a high standard of construction with permanently closed doors and controlled systems of general ventilation. In the restricted atmospheric conditions so produced, the leakage of carbon monoxide from cupolas became a serious matter, and it was shown that concentrations as high as 0.1% might occur around the base of a cupola.

Our Sub-committee discussed the possibility of carbon monoxide leaking from cupolas into the foundry atmosphere, and at their request the British Cast Iron Research Association did a good deal of work on various aspects of the matter, and some of the results were published in 1954.[33] We have included a summary of the work, with the conclusions, in Appendix XI.

45. *Heating Stoves and Open Fires*

Coke burning stoves for space heating are used either with a flue discharging the products of combustion into the open air, or with a flue terminating in the foundry. It is usually suggested that this latter method must be used because flues extending to the foundry roof would prevent the passage of overhead cranes. It is obvious that any carbon monoxide produced will pass into the foundry atmosphere if the stove is not fitted with a flue which leads to the outside air. No experimental work has been done on these slow combustion stoves for the purposes of this report, but it is known that 'natural draught' coke fires will give up to 10% carbon monoxide in the products of combustion,[33] and it may be that this figure will be exceeded for a short time after filling the fire with a charge of cold coke. While we are aware that Section 3 of the Factories Act, 1937 requires the provision of proper flue systems for these stoves, on purely technical grounds we are of the opinion that they should always be fitted with flues to take the products of combustion to the open air.

Coke braziers have been used to heat foundries and often enough no flue system has been provided. These will be prohibited after 1st January, 1956 by Regulation 7(1) of the Iron and Steel Foundries Regulations, 1953. No experimental work has been done for your committee on the carbon monoxide content of the products of combustion of these braziers, used at floor level, but tests taken from braziers sunk below floor level in a mould cavity have shown[4] [33] a concentration of carbon monoxide as high as 0.86% with a CO/CO_2 ratio of 0.022.

46. *Core Stoves*

It has not yet been possible to make any tests on core stoves, but there is little doubt that dangerous concentrations of carbon monoxide can be generated in the stoves. Generally this is a matter of no significance because the flue gases pass to the open air. On the other hand, some carbon monoxide may enter the foundry atmosphere if stove doors are left open, when the fires are burning.

47. *Poured Moulds*

Poured moulds are a further source of carbon monoxide if the vents are not lighted, and also after lighted vents have gone out. Concentrations of 0.045% carbon monoxide have been recorded in samples taken close to mould vents which have not been lighted, [33] and in one case an unlighted vent stream gave 0.224% carbon monoxide. These figures may be insignificant if a small number of boxes are in this condition in a well-ventilated foundry, but may merit consideration in foundries engaged in continuous pouring. We have not estimated the carbon monoxide content in the foundry atmosphere from this source, other work having been done in preference because we did not consider that the poured boxes constituted a major risk in British foundries. On the other hand it should be appreciated that they contribute carbon monoxide to the general atmosphere of the foundry, and vents should always be lighted. Obviously a continuous casting process will produce more carbon monoxide from this source than the intermittent casting of small numbers of boxes.

48. *Mould Drying*

The Joint Advisory Committee recommended that " No ordinary open fire should be used for mould drying, other than in exceptional cases where it can be shown to be unavoidable."[1] They appreciated that flue systems could not be fitted to portable mould dryers, but on the information then available, took the view that little risk could be anticipated from their use. In consequence they recommended the use of portable mould dryers, to the exclusion, wherever possible, of the open fire for mould drying.

In view of the remark of the Joint Advisory Committee that they had " not been able, in the time available, to make exhaustive tests,"[1] and because they indicated that their information only " tended to confirm that there would be little risk of injurious or offensive fumes or smoke "[1] from portable mould dryers, we referred the whole subject to our Technical Sub-committee. A good deal of experimental work has been done for this Sub-committee by private firms and by the British Cast Iron Research Association, in order to determine the amount of carbon monoxide that might be present in the products of combustion from both open fires and mould dryers. The Sub-Committee carefully examined the results and have now presented us with their Report[4] which has already been published.

The Report of the Joint Advisory Committee referred to the use of radiant heat for mould drying and also recommended that " sufficient stove capacity should be provided to take all work which can be stove dried," but neither of these matters was discussed by our Sub-Committee. They closely examined, however, three other points raised by the Joint Advisory Committee. These were : (1) the use of open fires for mould drying ; (2) the use of portable mould dryers for mould drying ; (3) the divergence of opinion amongst foundrymen as to the range of work over which mould dryers can be used.

The first two points involved extensive analyses of the products of combustion from different types of mould dryers operating in different conditions. This work has been completed and used by the Sub-Committee as a basis for recommendations which are reprinted in Appendix XII. The third matter is still under consideration. The Sub-Committee is in agreement with the remark in the Report of the Joint Advisory Committee that, " experience and skill would be required before they (mould dryers) could be applied successfully to all types of moulds." The Sub-committee are satisfied that mould dryers should be used, and consideration is now being given to the possibility of preparing a report which would indicate the best methods of applying them to a mould, and show also some of the practices used by experienced foundrymen to overcome difficulties in mould drying by meansof portable dryers.

The question of combustion is discussed in the published Report[4] and we think that this document warrants the close attention of all those who are interested in the manufacture or use of portable mould dryers. It contains general discussions on such matters as the CO/CO_2 ratio, types of coke, depth of fuel beds, air supply and the completeness of combustion. It also has seventeen appendices, which give the results of the experimental work that has been done.

49. *Open Fires*

Gas analyses were made on the products of combustion from open coke fires which had been placed in pit moulds in the normal fashion for the purpose of mould drying.[4] It was found in one case that the carbon monoxide concentration inside the mould rose to a figure as high as 0.62%. TheJoint Advisory Committee discussed the nuisance caused by smoke from open fires used in mould drying, but quite apart from this aspect of the matter we are satisfied that braziers in the confined space of a pit mould may give sufficiently high concentrations of carbon monoxide to be dangerous to persons entering the mould, and we have no doubt that open fires should not be used for mould drying, except in exceptional circumstances, and then only if adequate precautions against gassing are taken.

50. *Coke Fired Portable Mould Dryers*

Most of the experimental work was done on coke fired portable dryers and carbon monoxide determinations were made on fan blown dryers and on dryers which used induced air from a compressed air ejector system. The dryers were tested under a wide variety of conditions, and efforts were made to obtain the maximum possible concentration of carbon monoxide. To this end many of the dryers were tested in conditions chosen to give incomplete combustion. The full results are given in the report already mentioned,[4] but the Sub-Committee concluded that, " mould dryers gave much less carbon monoxide than open coke fires, and therefore, we consider that the latter should not be used, except where their use can be shown to be unavoidable. Although appreciable concentrations of carbon monoxide may be evolved from mould dryers, none of the dryers examined showed dangerous concentrations, even in the worst period following a charge of cold coke, provided that the back pressure was less than 1" water gauge. This condition can readily be fulfilled if adequate free outlets are provided from the mould."

51. *Gas Fired Portable Mould Dryers*

One series of tests was done on a gas fired mould dryer operating against a back pressure of 1.9" water guage.[4] Even in these conditions the carbon monoxide concentrations were substantially lower than those given off from coke fired dryers, and this was true in all operating conditions. The Sub-Committee commented that " probably the main risk from gas fired dryers comes from the risk of leakage of unburnt gas from the flexible connections."

The results of this work on mould dryers justified the recommendations of the Joint Advisory Committee on the subject. The recommendations of the Report on the Drying of Moulds by Portable Dryers[4] are reprinted in Appendix XII.

52. *Electric Mould Dryers*

We have noticed with interest the development of electric mould dryers in foundries overseas. No objectionable fumes or gases escape from these dryers, and where they can be used they give the best atmospheric conditions. For this reason we should welcome their introduction into British foundries.

53. *Ladle Drying*

Many of the considerations which apply to mould drying also apply to ladle drying, and the problem has been passed to our Technical Sub-Committee. It has not yet been possible to examine it in the same way, and we have nothing at present to add to the recommendations of the Joint Advisory Committee.

SULPHUR DIOXIDE

54. The discussions on open fires and mould dryers in the Report of the Joint Advisory Committee include references to the fumes which may be emitted into the foundry. The most irritating fraction of these fumes from coke fires and dryers is sulphur dioxide, which was discussed by our Sub-Committee during their deliberations on mould drying.[4] Sulphur dioxide is an irritating gas which has a detectable odour in concentrations 3—5 parts per million. Concentrations above 20 parts per million cannot be tolerated. Its presence in the fumes from coke fires and dryers is an added reason why all flues should be taken outside the foundry. We are informed that it is not possible to fit flues to portable mould dryers, and consequently the only precaution to be taken if empolying a coke fired dryer is to use coke with a low sulphur content. Another remedy would be to use electrically heated portable dryers.

CORE BINDERS

55. The Joint Advisory Committee drew attention to the irritating and objectionable fumes that may be given off when certain kinds of binders are used in core making, and remarked on the possibility of a health risk in one specific case. We decided that further work was necessary on this complicated matter before any useful opinion could be expressed. We remitted the whole subject of core binders to our Technical Sub-Committee which has indicated several approaches to the problem, namely : (1) the development of new core binders which would give no objectionable products of decomposition ; (2) the careful and correct use of existing binders so that a minimum amount of fumes would be generated ; and (3) the use, whenever practicable, of ventilating devices to control fumes after they had been generated.

These three lines of approach were set out in a different order in an earlier publication.[3] The Sub-Committee did not give much attention to the third method because it was thought that exhaust ventilation could well be applied in suitable conditions ; one example being the use of ventilated tunnels after casting on a conveyor belt in a mechanised foundry. There are however, occasions where local exhaust ventilation is impracticable and in these cases the first and second methods become the most important. A Report of our Sub-Committee's findings on the second method has been published[3] and so far as the first method is concerned we have noted with interest the introduction of a new carbon dioxide process in connexion with the making of moulds and cores.

56. *Abstract of Literature*

Our Sub-Committee was fortunate enough to receive much assistance from an interested iron founder, who is also an organic chemist. He prepared for us an abstract of existing literature on the break-down products of many materials used as core-binders. This abstract,[2] was published in 1949, and together with a second abstract given in Appendix XIII, will serve as a basis for future work.

57. *The Reduction of the Amount of Fumes from Oil Bonded Cores*

The Joint Advisory Committee had remarked, in Section 47 of their Report that "much more attention to technical control of operations in core shops seems to be needed."[1] Our Sub-Committee has published a series of recommendations [3] on the subject. The reasons for these are discussed in the text, which deals with the storage of binders, the size distribution of the sand, the temperature of the sand, mixing, the storage of the mixed sand, baking, casting and types of core or mould. We are of the opinion that this document warrants careful consideration and a summary of the recommendations is reprinted in Appendix XIV.

58. *Synthetic Resins*

Our Sub-Committee also dealt with the use of synthetic resins and a member of the Sub-Committee published a survey of the subject[35] in 1949. As a result the Institute of British Foundrymen set up a Technical Sub-Committee under tbe chairmanship of Mr. G. L. Harbach. They reported on the subject[36] in 1951. The following conclusions[36] were reached :

> "As to implementing the recommendations of the Garrett Report (*i.e.* the Report of the Joint Advisory Committee[1]) the Sub-Committee is of the opinion that P.F. (*i.e.* phenol formaldehyde) resin approaches the ideal of a practical and fumeless core binder. Nevertheless the economic attractions of U.F. (*i.e.* urea formaldehyde) resin and the fact that fumes from the cereal portion of the mixture are inevitable, whichever resin is used, emphasize that good ventilation, together with the use of minimum percentage binder and thoroughly baked cores are the most practical means of improving conditions in foundries."

The matter is still receiving attention, and while at the present time we can do no more than endorse this conclusion, other work will have to be undertaken in the light of later developments.

59. *Analysis of Fumes from Core Binders*

Our Technical Sub-Committee has been dealing for some years with the question of analyses of the fumes from core binders. It is a difficult matter, because it is not easy to collect the fumes, some of which are gases while some may be in the form of a mist of liquid droplets. Again when the fumes are collected the organic analyses is extremely complicated and calls for a high degree of skill and patience from the analyst. Further, the products of decomposition differ with different binders, and it might be expected that identical results will not be obtained in two cases where the same binder is used for different castings in different conditions. Presumably the heat content of the sand surrounding the metal will influence the composition of the break-down products from the core binders.

Experimental work was started at Loughborough College,[43] but for a variety of reasons this effort had to be abandoned. Our Sub-Committee then gratefully accepted an offer from a foundryman which has resulted in a method of collecting the products of decomposition from binders in sufficiently large quantities for chemical analysis. This method is embodied in Appendix XV.

NEW PROCESSES

60. (*a*) *Shell Moulding*

The relatively new process of shell moulding is now passing out of the experimental stage into production. We are watching this development with great interest because we think that the process can give great improvements in working conditions if properly applied. Certainly, the finish that can be achieved on castings should reduce greatly the dust problem in the dressing shop. There are, however, certain stages in the process which produce dust and fume and which require careful control. The matter is under our active consideration.

(*b*) *Carbon Dioxide Process*

This process, while still largely experimental is also under careful consideration.

ACCIDENT PREVENTION

61. *Accident Analysis*

Though most of our report is devoted to the prevention of industrial diseases in iron foundries, the equally important problem of accident prevention in the industry has had much attention from your committee.

Our Secretary has made a detailed analysis of all iron foundry accidents involving more than 3 days' incapacity (and so legally reportable to the Factory Department). This analysis will be found in Appendix XVI and is worthy of careful study.

We have considered these tables in conjunction with other information made available to us and we have arrived at the following conclusions :

(1) During recent years most foundry accidents have fallen consistently into a relatively small number of causation groups, the two principal groups being (*a*) handling articles (including the lifting of heavy weights) and (*b*) the movement of molten metal.

(2) These two groups account for over 50% of the total foundry accidents each year and a large proportion of these accidents result in three characteristic types of injury, *viz* :—(*a*) molten metal burns (including many foot and eye injuries), (*b*) strains, hernias, etc., (*c*) cuts, abrasions and bruises (again including many foot injuries).

Strains, etc.

We realise, as a committee, the practical impossibility of marking the weight on every piece of equipment and on every job in the foundry. We do not think it practicable to lay down standards of maximum weights because man is not a standardised machine and physique varies from individual to individual. We therefore suggest for consideration, the two following remedies :

(1) Education of the workers, especially the younger generation, in the correct methods of manual weight lifting.

(2) Increased application of mechanical handling.

Cuts and Abrasions (*Sepsis*)

Cuts and abrasions to the hands could either be prevented or at least greatly reduced in severity by the provision and use of gloves or other forms of hand protection. In this connexion we would also advocate a stricter insistence on immediate first-aid treatment for such injuries, together with education of the workpeople as to the urgent necessity for reducing the on-set of sepsis. The sepsis record of the iron foundry industry compared with the general sepsis rates of industry is unsatisfactory because nearly 50% of the cuts and abrasions due to the handling of material become septic.

Burns. As might be expected, burns from molten metal form a substantial proportion of the yearly total of iron foundry accidents and most of them occur during the handling of molten metal. Many follow as the result of spillage caused by tripping or stumbling over irregularities in floors, gangways and pouring aisles or over loose articles left carelessly in such places.

We are satisfied that higher standards of tidiness and the proper maintenance of floors, etc. could do much to reduce this class of accident.

All too frequently we note that a secondary or contributory factor of these accidents is the failure either to provide or wear protective appliances.

62. *Treatment of molten metal burns*

The accident rate in the founding industry is high and we wish to emphasise the need for having in each factory adequate facilities for rendering skilled first-aid treatment. The larger and more progressive firms have well-equipped ambulance rooms or surgeries under whole or part-time medical and whole-time nursing supervision. This is the best arrangement both for the management and the workers, because in many ways it saves manpower, time, money and even life. The smaller firms would be well advised to institute such medical and nursing services on a relatively more modest scale. But where only the main requirements prescribed by law are available, *i.e.* first-aid boxes in charge of first-aid workers, it is essential that the latter should be specially trained in the first-aid treatment of molten metal burns.

We have been told that the molten metal burns (which form a large proportion of all foundry accidents) have certain features which call for early surgical treatment (excision and skin grafting) in hospital by a skilled team of surgeons. Further, that when the burns are treated in this way, the time lost from work is reduced to a minimum. We recommend that the question of establishing special teams for the treatment of burns be considered by the hospital authorities in all areas where there are concentrations of foundries. Excellent services have been established in Birmingham (at the Birmingham Accident Hospital) and also in Glasgow. First class work in the treatment of burns is also being done at the Luton and Dunstable Hospital. There may well be up-to-date facilities for the treatment of burns at other hospitals but we have no first hand knowledge of them.

We are also advised that the best first-aid treatment for molten metal burns is one that does not interfere with subsequent hospital treatment. Briefly it consists in the application of a dry sterilised dressing to the injured area, the institution of first-aid measures for the treatment of pain and shock and in the rapid transfer of the patient to hospital.

63. *Eye Injuries*

Of the eye injuries, the commonest causes are :

(*a*) grinding with the use of abrasive wheels,

(*b*) dressing and fettling with pneumatic or hand tools,

(*c*) splashing from molten metal during tapping, carrying or pouring.

Nearly all these accidents could be prevented by the provision and use of proper goggles or eye screens.

We are aware that there are certain statutory provisions requiring these preventive measures, but we feel that there may be at times special difficulties in certain cases in category (*c*); men from mistaken motives, will often refuse to wear goggles or face screens even when suitable types have been provided for them. Many cases arise, however, where the goggles provided are unsatisfactory, *e.g.* because they become misted through lack of ventilation, thus obscuring the vision and creating a greater danger. While face screens properly adjusted are an extremely valuable form of protection they are not always satisfactory and we feel that more work is necessary to develop suitable goggles. We are therefore glad to note that you have set up a Committee representative of the three foundry Joint Standing Committees to examine this question.

We can see no valid reasons why some form of eye protection should not be worn by men engaged in grinding, dressing or fettling. We should, however, like to draw your attention to another problem, that of the man who, having temporarily removed his goggles while so engaged and for some purpose, *e.g.* to clean them or to call a crane, is thus left unprotected not from his own actions but from the actions of nearby workers such as other men fettling castings. Several severe accidents, we are informed, have been so caused.

We therefore strongly recommend that screens should be voluntarily provided whenever practicable (in addition to the wearing of goggles as required by law) to meet such a risk, and we are glad to note that you have already directed the attention of the industry to this matter.

We fully appreciate the difficulties where the fettling of very large castings is concerned, but in many of the cases we feel that the observance of our recommendation would go far to reduce this risk.

Foot Injuries

Many of these accidents arise either through spillage of molten metal, precautions against which have already been suggested or through the dropping of articles in the course of handling. In either case the wearing of suitable safety boots is largely the answer. We are anxious to see their use more widely adopted. To that end the recent agreement negotiated between the employers' and workers' organisations in the industry as to the provision, at cost price, of a type of safety boot acceptable to you will do much to improve matters. We would appeal to those at risk to provide themselves with this simple and economical form of foot protection. We know of many cases where the wearing of such boots has prevented what would otherwise have been severe injuries.

64. *Other causes of Accidents*

(1) *Power driven machinery.* While the proportion of accidents so caused is low compared with that of industry in general, we are of the opinion that this is due mainly to the lesser use of such machinery in iron foundries. The greater mechanisation of the foundry industry may, however, bring new dangers in its train. Makers of such machinery should, in our view, bear in mind the possible risks at the drawing board stage of design and should see to it that this vital matter is in no way neglected in any machine supplied for use in foundries. We would therefore ask you to draw the attention of designers and suppliers to this recommendation.

(2) *Lighting.* We have no means of estimating in how many cases inadequate lighting has been a contributory factor in the causation of accidents, but there can be no doubt that good lighting, both natural and artificial, will help towards their reduction.

We would add that good lighting shows up dust and dirt and is therefore an incentive to the tidiness and cleanliness which we have already advocated.

65. *Organisations for Accident Prevention*

We are pleased to report that constantly increasing attention is being paid to this important matter by the industry. The employers' organisations have formed an Accident Prevention Committee to investigate the problems and the means of tackling them. To that end the C.F.A. Conference held at Ashorne Hill[8] under the chairmanship of one of our own members (Mr. Colin Gresty) in March, 1954, should do much to focus the searchlight of enquiry on the subject. We have noted that the proceedings of that Conference have been published[8] and commend it as being worthy of the widest publicity.

Conclusions at which we have arrived quite independently from a study of the analysis prepared by our Secretary are fully in line with the opinions expressed by speakers at that Conference.

On the Trade Union side too, we are fortunate in having among our members several prominent officials who have given us active support not only in our deliberations but in their wider association with the workers whom they represent. The Amalgamated Union of Foundry Workers, which is a full member of the Royal Society for the Prevention of Accidents has, for example, published and circulated to its members an admirable booklet[37] which summarises the legal requirements affecting these matters and draws attention not only to the rights of the workmen but also to their responsibilities. This branch of the Union's activities always occupies a prominent place in the agenda for their Annual Conference of delegates, as well as being stressed in their local branches.

66. *Foundry Accident Prevention*

There is room, we are convinced, for some domestic arrangement in every foundry. It is true that many firms already have Committees, but we think that new ground remains to be broken. It is scarcely necessary in this Report to go into the question of the composition of Safety committees, but experience has shown that the best results are obtained where there exists a really keen interest in this work both on the part of the management and of the employees, and it is a well established principle that both sides should be equally and fully represented.

67. *Summary of Conclusions*

The main point which has emerged from the analysis of foundry accidents (Appendix XVI) is that the yearly totals could be very considerably reduced by a concentrated and determined attack on the main causation groups, but if a campaign of this nature is to be successful, we feel that two things are essential,

(*a*) there must be really keen interest and determination to succeed on the part of the management, and

(*b*) this must be supported by equally keen interest and the fullest co-operation on the part of the workmen.

The lines of action which would appear to be most promising in the reduction of these accidents are as follows :

(1) A much higher standard of housekeeping, especially as regards the provision and maintenance of better floors and gangways, with particular attention to obstructions on such floors and gangways.

(2) The wider provision of more suitable protective clothing and other protective devices.

(3) The proper care and use of such protective equipment by the workmen.

(4) Early first-aid treatment.

(5) Better instruction in safe methods and practices with particular attention to weight lifting.

(6) The setting up of some domestic organisation or arrangement in every foundry, whereby accident prevention measures can be discussed and dealt with jointly by management and employees.

FINAL REMARKS

68. This is in the nature of a first report with a number of problems still remaining. We feel, however, that some progress has been made by your committee in carrying out the task with which you entrusted us in 1947.

69. *Acknowledgements*

We desire to express our grateful thanks for the valuable help we have received from the British Cast Iron Research Association and Foundry Atmospheres committee as well as from the other technical organisations, private firms and individuals whom we have consulted from time to time.

We must also pay tributes to our former chairman, Mr. H. A. Hepburn, C.B.E., formerly H.M. Deputy Chief Inspector of Factories until his retirement in 1953, to Mr. H. Woods our former Secretary, to Mr. W. B. Lawrie, M.B.E., who was also our Secretary for a time as well as undertaking numerous enquiries on our behalf and also to our present Secretary, Mr. W. A. Attwood.

We are also indebted to our medical member Dr. A. I. G. McLaughlin, for his advice and guidance on the medical aspects of our work.

70. We hope that you will see your way to publish the results of our work as a guide to the Industry as we recommend in para. 4.

We have the honour to be Sir,
Your obedient Servants,
(*signed*) T. W. McCullough (*Chairman*)
J. D. Dobson
J. Gardner
P. Leonard Gould
Colin Gresty
E. C. Happold
A. Hardy
J. Higham
W. B. Lawrie
A. I. G. McLaughlin
J. Owen
A. E. Pearce
H. V. Shelton
J. H. Wigglesworth
W. A. Attwood (*Secretary*)

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APPENDIX I

THE EXTERNAL DUST CONTROL SYSTEM

(14″ STAND GRINDER)

1. One of the earliest results of the rapid dust estimation method, and the observation and cinematography of dust clouds, was the demonstration that conventional local exhaust ventilation systems fitted to stand grinders were not always as successful as had been supposed. the original work [17] was done on a 24″ diameter wheel running at a peripheral velocity of 9,000 feet per minute. Plate 2 shows the conditions which were found. It was evident that the fine dust, generated by grinding, followed the wheel round and was ejected at high velocity from the guard opening at the top of the wheel. As a result of these observations it was decided to explore the effects on a smaller wheel running at a lower velocity. This work was done under the Foundry Atmospheres Committee by one of our members in collaboration with a member of the staff of the British Cast Iron Research Association, and was published in 1952.[20] It was found that the smaller, slower wheel showed similar aerodynamic characteristics to the larger one.

2. These investigations[20] after a close examination of the earlier published work, drew the following conclusions :

(1) It was desirable to devise new and more efficient means of dust control for pedestal grinders.

(2) The use of a high velocity low volume air curtain might be more efficient, and would in any case offer the advantage of a lower air volume with a corresponding reduction in air losses and heating costs.

(3) Conventional dust extraction methods might not be capable of reversing the high velocity air stream, developed by the wheel, which had been shown to carry the dust out of the cowl. If this were true, the fan effect of the wheel would have to be considered as an integral part of the extraction system.

(4) More fundamental information was needed with reference to the direction and velocity of the air currents set up in the working area of an abrasive wheel rotating in space.

3. Work was begun on a 14″×2½″ wheel rotating at 1,400 revolutions per minute with a peripheral velocity of 5,000 feet per minute and fitted with a normal type of dust extraction unit. The preliminary work was directed towards the elucidation of the aerodynamics of the system, and the zone of influence of the rotating wheel was explored by means of the observation and photographic method[17] as well as by measurements of air velocity taken with a Metropolitan Vickers Velometer. The work was done both with and without the conventional local exhaust ventilation system in order to estimate the effects of the system.

4. Early photography showed that the dust distribution from the wheel conformed to the general pattern discovered on the 24″ diameter wheel,[17] and Plate 4 shows the primary dust stream flowing down the wheel face, along the work and up the operator's body towards his face. This photograph, which may be compared with Plate 2, was taken when the conventional exhaust system was fitted and operating. The dust streams which had been observed and photographed were explored by means of the Velometer and Figure 1 shows the air movement due to the rotation of the wheel. These results were obtained when the local exhaust system was not in action and so they represent the aerodynamic effects of the rotating wheel itself. It is evident that

the wheel acts as a fan, and that this effect should not be ignored when designing dust control systems.

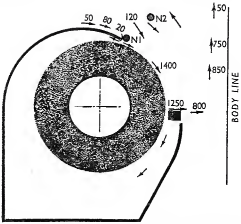
50
80
20
120
N2
N1
50
750
1400
850
1250
800
BODY LINE

Figure 1. Air movement due to the rotation of the 14″ diameter wheel. Exhaust not operating. Figures indicate air velocities in feet per minute.

Illustration by courtesy of The Institute of British Foundrymen.

Full details of the work appear in the published paper,[20] but it was finally shown that the dust streams indicated in Figure 2 would have to be collected if the local exhaust system was to be efficient. The following conclusions were reached at this stage of the work :[20]

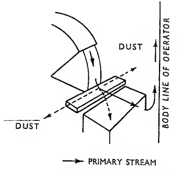
DUST
DUST
BODY LINE OF OPERATOR
PRIMARY STREAM
SECONDARY STREAM

Figure 2. Dust streams requiring collection if the extraction system is to be efficient.

Illustration by courtesy of the Institute of British Foundrymen.

"(1) That much of the dust followed the wheel round and was ejected at high velocity at the cowl opening.

(2) That conventional local exhaust ventilation systems seemed to be incapable of reversing this dusty air stream and so controlling the dust.

(3) That between the cowl and the face of the operator there was a zone penetrated by sundry air currents.

(4) That these currents moved at relatively low velocities.

(5) That this zone included at least two neutral points at which no air movement could be recorded."

5. It appeared therefore that the primary dust stream which flowed down the wheel face at velocities up to 3,000 feet per minute was not reversed by the conventional local exhaust system because of its high velocity. It was also obvious that it could be more easily controlled after decelerating outside the conventional hood by means of low air streams moving at relatively high velocity. In addition to the dust stream flowing down the wheel face the other streams shown in Figure 2 would have to be collected if the system were to be efficient. These results led the two investigators[20] to proceed with a design incorporating the following features :

"(1) A high velocity low volume air curtain was to be used.

(2) The extraction system was to be external to the wheel cowl and collecting box.

(3) Provision was to be made to collect the dust which flowed along the rest, parallel to the wheel axis.

(4) Provision was to be made to collect the heavier dust together with any dust which might leave the work rest or the casting in a downward direction and move towards the feet of the operator."

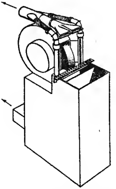

Figure 3. Prototype fitted with nozzles.

Illustration by courtesy of The Institute of British Foundrymen.

6. In this small wheel the conventional exhause system was removed completely, and the dust produced when grinding was allowed to leave the wheel cowl before being collected. The new local exhaust ventilation system operated therefore externally to the cowl so that the system became known as the "External Dust Control System." Figure 3 shows the final prototype, in which the dust from the primary stream is collected through the nozzles mounted above the wheel hood. The two vertical pipes, placed one on each side of the wheel, serve to collect the dust which flows along the work rest ; the hopper in front of the rest collects the heavier dust which is projected downwards from the work. The air velocity entering the top nozzles was 5,000 feet per minute, that entering the side ducts was 3,500 feet per minute, and the velocity

at the rim of the small hopper was 1,000 feet per minute. The total air volume used on the machine was about 450 cubic feet per minute.

7. Each step in the development work was recorded on 35 mm. cinematograph film,[20] and the efficiency of the new external dust control system is indicated by Plates 5 and 6. The effect of the conventional local exhaust system which was discarded is seen in Plate 4, whilst Plate 5 shows the wheel operating on pig iron without local exhaust ventilation. Plate 6 illustrates the normal dust control obtained with the new external system fully operative, and with pig iron still being ground as in Plate 4 and Plate 5. Finally the observations and the photographs were confirmed by means of dust counts made on Owens Jet Counter samples and on Thermal Precipitator samples. Full details of these dust counts appear in the published paper.[20]

8. The two workers drew the following conclusions :[20]

"(1) It has been sbown that the phenomena found on a grinding wheel running with a peripheral velocity of 9,000 feet perminute, which were described in a previous paper,[17] also appear on a wheel running at a peripheral velocity of 5,000 feet per minute.

(2) The primary dust stream which flows down the face of the rotating wheel and sundry secondary air streams which develop therefrom have been photographed by means of a cinematograph camera.

(3) The necessity for dust tight dust collectors has been shown by photographs of a dust cloud of about 2,000 particles per cubic centimetre, which was found to be leaking continuously from a collector unit which was under pressure from the fan.

(4) It has been found that, in cases where the dust moves in well defined streams, dust samples taken in standard conditions when the dust is invisible may give erratic results. It appears that these variations in the results are often due to the fact that the instrument may fail completely to sample the main dust stream, and may be collecting from a much cleaner air stream moving alongside the dust stream. It appears therefore that visual dust observations are desirable to supplement dust counts.

(5) Observations have shown that the dust control achieved by the new external exhaust system is superior to that obtained by the conventional method of ventilation, in the experimental conditions imposed. Even when heavy dust clouds momentarily burst through the high velocity air curtains, the dust was quickly recaptured by the system.

(6) Observations have suggested that nozzles are at least as good as, if not better than, the long extraction arms.

(7) Thermal Precipitator dust counts have shown that the new system is capable of controlling dust clouds so that the breathing zone concentration remains below about 750 particles per cubic centimetre even when the cloud generated is of the order of 60,000 particles per cubic centimetre. In these conditions of gross overload the average breathing zone dust concentration lay between 400 and 500 particles per cubic centimetre."

APPENDIX II

THE COMBINED DUST CONTROL SYSTEM

(24″ STAND GRINDER)

1. When the development work had been completed on the 14″ diameter wheel, running at a peripheral speed of 5,000 feet per minute the Foundry Atmospheres Committee decided that it was essential to explore also the aerodynamics of a 24″ diameter wheel with a peripheral velocity of 9,000 feet per minute. Once again the experimental work was done in the laboratories of the British Cast Iron Research Association by a member of their Staff and one of our Committee members.[21]

2. The external system already developed on the 14″ diameter wheel was applied to the 24″ diameter wheel. It was found, however, that the standard dust collecting box fitted to the machine was too small to release the pressure generated by the running wheel. This resulted in dust being blown out of the collecting box and the external system was overloaded to such an extent that it did not give adequate dust control. It was evident that the pressure in the collecting box must be relieved, and it was decided to do this by connecting it to the fan in the conventional manner. This resulted in the combined dust control system shown in Plate 7. The exhaust duct in the back of the dust collecting box releases the air pressure set up by the wheel, and also extracts some of the dust. The external exhaust system, applied over the top and down each side of the wheel collects the dust which either leaves, or fails to enter, the wheel guard. In addition to these arrangements the work rest was perforated and mounted directly on top of the collecting box.

3. The system was tested in laboratory conditions using a 24″ diameter wheel and a 16″ diameter wheel. The smaller wheel was used in order to estimate the effects of wheel wear on the ventilating system. Neither the observation technique nor the Thermal Precipitator dust counts showed any significant difference in dust concentration (at the breathing level of the operator) between operating conditions and general atmospheric conditions before commencing work. This indicated the efficiency of the prototype, and the conclusion was valid both on a new wheel of full diameter and on a worn wheel. The combined system, in the conditions obtaining at the time, was controlling all the dust generated by the grinding process. The Thermal Precipitator counts were not incinerated, in order to retain all the dust produced, and were counted in standard conditions on an optical microscope. Dust particles were counted down to the limit of visibility in light field illumination.

A further point of interest appeared from the results of these tests. Grinding machines are normally fitted with an adjustable flap at the guard opening, at the top of the wheel This flap should be lowered as the wheel wears in order to maintain a minimum gap between the guard and the wheel top. In practice, however, this adjustment is not always made as carefully as it should be, and in the conventional local exhaust systems it may affect the efficiency of dust control. The tests on the combined exhaust system, however, showed that the magnitude of this gap between the wheel top and the guard did not influence the efficiency of the dust control method. Even when the gap was increased to 4½″×3½″ by using a 16″ diameter wheel, the experimental system still retained control of the dust.

Full experimental details have already been published.[21] Plate 8, a 'still ' taken from the cinematograph film, shows the dust cloud being cut off at the top nozzle, well below the breathing level of the operator.

4. The work on the 24" diameter wheel led to the following design and conclusions :

Design

(1) A perforated work rest was mounted directly on the top of the collecting box.

(2) The pressure in the collecting box was relieved and some of the dust collected by applying part of the ventilating air in the conventional manner through a duct fitted to the back of the collecting box.

(3) The external system was fitted to the top and sides of the wheel to collect the dust which either left, or failed to enter, the wheel guard.

Result

The combined system was tested in laboratory conditions. Neither the observation technique nor the Thermal Precipitator dust counts showed any significant difference (at the breathing level of the operator) between operating conditions and general atmospheric conditions before commencing work.

Conclusions

(1) The system was equally effective on a 24" diameter wheel and on a worn wheel of 16" diameter.

(2) The gap between the wheel top and the guard did not influence the efficiency of the dust control. (Even when this gap was increased to 4½ by 3½ inches, by using a 16" diameter wheel, the experimental system still retained control of the dust).

APPENDIX III

DUST CONTROL FOR A PORTABLE GRINDER

1. Light castings can be put on a bench fitted with local exhaust ventilation if they are to be ground with portable grinders. There are many kinds of work, however, which cannot be done on such a bench, and the portable machine has been commonly used without dust control of any kind. The effects of this method of working are shown in the dust concentration figures to which reference has already been made.[12] In consequence two members of an industrial firm and a member of our Committee[22] together began research on the problem in 1953, in an effort to develop a dust control system which would provide protection from the dust, and at the same time form an integral part of the machine. It was obvious that the dust control system would have to be inconspicuous and very light in weight, in order that the portable machine should retain its flexibility of operation. This being the first time any attempt had been made to exhaust dust through the guard of a hand grinder, the investigators had no previous experience to guide them. They decided therefore to examine the aerodynamics of the machine by means of the dust observation technique.

2. The work was done on a series 40 Holman grinder, fitted with a 6" diameter wheel with a free running speed of 6,000 r.p.m. and a peripheral velocity of 9,000 feet per minute. A 5" diameter wheel was also used during the tests in order to estimate the effect of wheel wear.

The wheel guard was fitted with a peripheral duct as shown in Plate 9. Three ports opened on the inside curved surface of this duct which was also connected to a ⅝" diameter flexible pipe. In the experimental work the exhaust was obtained from a compressed air Eductor as illustrated in Figure 4 although a rotary exhauster can be used for the purpose.

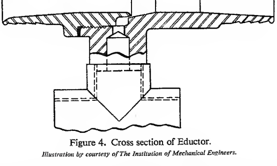

Figure 4. Cross section of Eductor.
Illustration by courtesy of The Institution of Mechanical Engineers.

The system represents a new development in local exhaust ventilation in that it employs a very low volumne of ventilating air moving at very high velocity. The dust generated by the wheel was controlled by 23.5 cubic feet of free air per minute, at a vacuum of 5"—6" of mercury, and the calculated velocity in the ⅝" diameter hose, through which the air and dust were extracted, was 11,500 feet per minute.

3. During the experimental work an air jet was tried in two positions. The jet was originally placed at the ' trailing ' edge of the guard, (i.e., at the edge at which the moving surface of the rotating wheel leaves the guard), and was directed against the movement of the wheel, blowing tangentially on to the wheel face. This attempt to strip the dust from the face of the moving wheel failed through the turbulence set up. The jet was then placed at the ' leading ' edge of the guard, (i.e. the edge towards which the rotating wheel moves as it leaves the point of contact with the work being ground). Here it assisted the exhaust system by increasing the amount of air drawn into the guard. It was evident, however, from the experimental work that the jet would have to be used with great care, and kept in critical adjustment to avoid turbulence ; otherwise the dust would be blown away from the exhaust system and dissipated in the general atmosphere. The air jet was therefore discarded because the necessary ventilation air could be induced more easily by suction methods, which were sufficient to strip the moving dust from the wheel face within the guard.

4. The prototype was examined by the illumination method and the effectiveness of the dust control achieved in laboratory conditions is shown by Plate 3 and Plate 10. Plate 3 is reproduced from earlier work[17] and shows the first photograph that was taken of a portable grinder working without exhaust ventilation of any kind. The fine dust can be seen above the wheel as it diffuses upwards to the operator's breathing level. Plate 10 was taken from the film used to assist in the development of the new exhaust system. It shows the fine dust under good control, even in the worst conditions with the leading edge of the hood lifted as far above the work as possible. The wheel is rotating in an anti-clockwise direction and is grinding grey iron. Heavy particles can be seen falling to the floor, and the main dust cloud is under control. The dust which has passed the leading edge of the guard is being brought back by the induced air on the right of the picture.

The machine was also tested when grinding wood, when it was found that no smoke left the wheel hood. The smoke may not follow the paths taken by dust when grinding metal, but this observation serves to indicate the efficiency of the local exhaust system on very small particles.

5. Preliminary dust counts were taken in laboratory conditions.[22] [23] The Owens Jet Counter showed a general atmosphere dust concentration of 200 particles per cubic centimetre before starting work. This increased to 300 particles per cubic centimetre at the breathing level of the operator after 7 minutes grinding on grey iron with the exhaust system working. Without the exhaust system 7 minutes grinding gave a dust concentration of 10,000 particles per cubic centimetre. Comparable results were obtained with the Konimeter. This instrument produced no recognisable spot from the general atmosphere before starting work. Grinding grey iron for 7 minutes with exhaust, lifted the breathing level concentration to 78-120 particles per cubic centimetre, while a similar grinding period without exhaust produced a Konimeter sample that was too dense to count. The Thermal Precipitator showed 139 particles per cubic centimetre in the general atmosphere before starting work. With the exhaust system working the breathing level concentration rose to 243 particles per cubic centimetre, and a similar grinding period without exhaust produced 3,278 particles per cubic centimetre.

6. The hood on which the system was developed covered a large proportion of the wheel face, and in consequence may be impracticable on certain work. As a result the investigators have made other hoods which are cut back in order to expose more of the wheel. Complete dust control is of course more difficult in these circumstances, but experimental work is still proceeding, and the machine is being used in practical tests on the floor of the dressing shop.

7. The following conclusions were reached by the research and development workers who completed the project :

(1) Dust control by local exhaust ventilation could be fitted to portable grinders.

(2) A very low volume of ventilating air, moving at very high velocity under a high vacuum, is necessary on the portable grinder. This is a new conception in ventilating practice.

(3) The moving dust can be stripped from the face of a rotating wheel inside the guard. This result was achieved by the use of a peripheral duct fitted with three ports through which about 24 cubic feet of free air per minute was extracted at a vacuum head of about 5 inches of mercury.

(4) The small ducts which are essential on hand tools to allow sufficient flexibility of movement result in air velocities of the order of 12,000 feet per minute inside the duct.

(5) The exhaust air may be induced either by a compressed air ejector or a rotary exhauster.

(6) The use of a compressed air jet to strip the dust from the wheel face was found to be both unnecessary and unsuccessful.

(7) A compressed air jet can be used to increase the amount of air induced into the system. Great care is needed in the adjustment of this jet if it is not to do more harm than good. The development work showed it to be unnecessary and so it was discarded.

APPENDIX IV

DUST CONTROL SYSTEM FOR A BENCH GRINDER

1. The successful development of the new high velocity low volume local exhaust ventilation system for a portable grinder led the investigators to consider again the problem presented by stand grinders. Since dust could be controlled on a 6 inch diameter portable wheel with an air volume as low as 23.5 cubic feet of free air per minute it appeared that a similar system might be developed for stand grinders, and it was clear that the low air volume would offer certain definite advantages in practice.

Work was commenced[23, 24] on a 6″ diameter bench grinder used to grind tools and small articles. This machine was, in fact a very small stand grinder, fitted with an, ordinary work rest and bolted to a bench.

The original idea was to apply the system which had been developed for the portable grinder. An attempt was made on a 6″ diameter wheel, running at a free speed of 6,000 revolutions per minute with a peripheral velocity of 9,000 feet per minute. It was found, however, that the system did not satisfactorily control the dust on the bench type machine.

2. As a result of this preliminary experimental work it was decided that the aerodynamics of the system should be explored by the illumination technique, and this led to a redesign of the port openings. The local exhaust ventilation was still applied through a peripheral duct of the type designed for the portable wheel, but the position of the ports was altered and vanes were added to the port openings. These alterations were made for two reasons. The first reason was simply to improve the dust control. The second reason was that a specific attempt was made to utilise the fan effect of the wheel itself.

It is clear that any rotating wheel acts as a fan and the investigators decided that an effort should be made to use the power that was available in this fan effect. When the preliminary work had been completed the system was applied to an 8 inch diameter wheel[23, 24] from which it appeared that the new port and duct design did in fact use the fan effect of the wheel to such an extent that it pumped air down the duct at velocities between 1,000 and 1,900 feet per minute, depending on the wheel diameter.

3. The vacuum was again induced by a compressed air ejector, as a matter of convenience, although a rotary exhauster could be used equally well. The air ejector was modified so that it induced about 40 cubic feet of free air per minute at a vacuum head of 3—5 inches of mercury. Apart from this slight alteration the ejector was similar to that used on the portable wheel and shown in Figure 4, Appendix III.

4. In the prototype machine the peripheral duct inside the guard was fitted with two off-take ports. A flexible pipe, $\frac{5}{8}$″ in diameter, was taken from each off-take and joined through a Y piece to a single flexible hose which was connected to the air ejector. Plate 11 shows the completed prototype.

5. The machine was tested when grinding steel, grey iron, wood and a second wheel chosen to produce a very heavy dust cloud. The air velocities generated in the vicinity of the wheel were explored when using wheels varying in diameter from 4″ to 8″, both with and without local exhaust ventilation.

These tests were done to estimate the effect of wheel wear on the exhaust system, and to determine its efficiency on different size ranges of dust, in widely vary concentrations. The final tests were done in conditions of gross overload which would rarely be met in normal practice.

6. Plates 12 and 13 were taken from the 35 mm. film negative used for the development of the system[23, 24] and they indicate the efficiency attained when grinding grey iron. Plate 12 shows the wheel running without exhaust ventilation while Plate 13 is the corresponding picture with the ventilating system fitted and operating. No visible dust is leaving the wheel hood in Plate 13. The grinding of wood gave similar pictures. The dense smoke streams produced were controlled completely by the new system and no smoke left the wheel hood. It is important to appreciate that the paths taken by the smoke streams may not coincide with those taken by dust from normal grinding operations, but the use of smoke as a tracer served to indicate the efficiency of the system on very small particles. Finally steel and an abrasive wheel were ground, and in the optical settings used no visible dust left the system.

7. Perhaps the most interesting point to emerge from this work has been the complete alteration of air movement caused by the very high velocity ventilating system. The previous work[17, 20, 21] has shown a typical air distribution in the vicinity of the rotating wheel. The salient feature was the primary air stream caused by the rotation of the wheel. It has been shown,[20] and repeatedly confirmed, that this primary air stream emerges from the top of the guard and flows down the wheel face at a velocity approaching half the peripheral velocity of the wheel. This dust stream can be seen in Plate 4. The present 8″ diameter wheel gave confirmation of this early observation The high velocity low volume ventilating system has resulted in the disappearance of this air stream, and has produced, in its place, an air intake at the guard opening above the wheel top. This is obviously due to the high vacuum at which the system works. This vacuum appears to be sufficient to maintain a negative pressure inside the hood even when the wheel is rotating. As a result there is an air intake at the point where the moving wheel face leaves the hood.

8. A short series of dust counts has been taken in laboratory conditions using an Owens Jet Counter and a Thermal Precipitator[23, 24]. The samples, which were not incinerated, were estimated by the method already described[9, 10] and the wheel was used to grind steel, grey iron and another wheel. The results showed that the exhaust system was controlling all the dust generated, and there was no difference in dust concentration at the operator's breathing level whether he was grinding or not.

9. The completion of this project led the research workers to the following conclusions :[23, 24]

(1) The low volume high velocity exhaust system has been applied to an 8″ diameter bench grinder.

(2) The fan action of the wheel itself has been used to produce a velocity of 1,000—1,900 feet per minute in the ventilating duct, apart from that given by the applied vacuum.

(3) The new system appeared to be sufficient to reverse the primary air stream which has been shown to flow down the face of grinding wheels. An air intake was measured at the guard opening at the top of the wheel where all previous work has shown air flowing out of the guard.

(4) The dust control system used 46 cubic feet of free air per minute at a vacuum of 3 inches of mercury.

(5) The vacuum can be induced either by a compressed air ejector or by a rotary exhauster.

(6) The dust control achieved was observed by the illumination technique, and estimated by a short series of dust counts made on Owens Jet and Thermal Precipitator samples. In the laboratory conditions imposed during the tests, the new exhaust system controlled all the dust generated by the grinding process.

APPENDIX V

DUST CONTROL SYSTEM FOR A PORTABLE SURFACE GRINDER

1. Large flat surfaces are often ground by means of a portable surface or disc grinder in which the side of the wheel is used for grinding and not the edge. These machines frequently produce very dense dust clouds, the control of which has been a matter of great difficulty. Various kinds of hoods and booths have been tried, but because the articles being worked are often large, and the surfaces to be ground are awkwardly sited it has proved impossible always to ensure that the operator will never work between the point of dust generation and the exhaust hood. Thus even when such hoods have collected dust from portable surface grinders, this dust has often been extracted through the operator's breathing zone. In these conditions while a hood may serve some purpose in extracting dust which would otherwise contaminate the general atmosphere of a building, it has little value to an operator who must breathe the dust laden air as it passes his head.

2. The problem was put, by a foundryman, to a member of the Committee and as a result research was begun on it by the same team as before[24]. The illumination technique was used to explore the dust movement generated by the wheel, to develop the dust control system and to estimate the efficiency of the completed unit. The low volume high velocity system of local exhaust ventilation was again applied.

3. Ventilation air was induced by an Eductor during the experimental stages (see Figure 4, Appendix III) but a rotary exhauster could be used equally well.

4. The completed prototype is shown in Plate 14. The wheel is surrounded by a ring through which the exhaust air is extracted by a ⅝" diameter flexible hose, which was coupled to the compressed air ejector. This ejector extracted 28 cubic feet of free air per minute at a vacuum head of 4 inches of mercury. The dust photographs in Plates 15—18 were taken from the 35 mm. film used during the development work.[24]
Plate 15 shows normal operating conditions when grinding a bath without exhaust ventilation. Plate 16 is the corresponding photograph when the new local exhaust ventilation system is fitted and operating. It will be seen that no visible dust is leaking away from the system. Plate 17 shows the machine in use on the edge of a casting and the new exhaust system was operating when this photograph was taken. It will be seen that the system controls the dust when the wheel is in contact with the work at two points. If the wheel is used with one point of contact only, as in Plate 18, there is a very slight leakage of dust.

5. The prototype was tested in laboratory conditions when grey iron was ground and dust samples were taken with an Owens Jet Counter and a Thermal Precipitator.[24] Both instruments indicated that the exhaust system was controlling all the dust generated. The tests were not sufficiently prolonged to determine whether or not there would be any increase of dust concentration at the breathing level during a full day's work, but taken in conjunction with the results of the illumination technique they indicate a high level of dust control.

6. The machine is now on trial in industry, but the research and development project produced the following conclusions :

(1) It has been shown that local exhaust ventilation can be applied to portable surface grinders.

(2) The low volume high velocity system has been satisfactorily adapted to work on this type of machine.

(3) The exhaust air can be induced either by a compressed air ejector or a rotary exhauster.

APPENDIX VI

AN INTEGRAL EXHAUST SYSTEM FOR SWING FRAME GRINDING MACHINES

BRITISH STEEL CASTINGS RESEARCH ASSOCIATION

1. *Introduction*

In its studies of the problem of dust control on swing frame grinders, the British Steel Castings Research Association has recognised three distinct and well-established methods which can be defined as follows ;

(1) to embody a local exhaust system in the swing frame grinder unit itself ;

(2) to conduct the grinding operations over or adjacent to a grating through which dust laden air can be extracted ;

(3) to operate the swing frame grinder in front of a booth that is coupled to an extraction system.

While each of these three methods was subjected to critical examination with the object of assessing their relative efficiencies and advantages, the main experimental work was concentrated on method 1, i.e. an exhaust system integral with the swing frame grinder machine.

2. *Dust flow characteristics*

A series of observations was carried out both in the B.S.C.R.A. Dust Research Station and under industrial conditions, of the dust flow characteristics of various types and sizes of swing frame grinding machines as a preliminary to original experimental work in this field.

Throughout these studies the observations of dust flow and the detection of dust have been based upon the Lawrie method of illuminating airborne dust, which enables the dust of respirable size range to be seen and photographed. Cinematograph film records were made throughout the experimental work.

Various types of swing frame grinders commonly used in the steel founding industry show the same characteristic pattern of dust flow, consisting of a *primary stream of dust* ejected tangentially from the point of its generation and a *secondary stream of dust* emerging from the wheel guard.

The primary dust stream consists of particles of a very wide range of sizes. Large particles are of no importance from the point of view of the health hazard, hut their influence on the flow of fine dust has to be considered. When grinding different materials, i.e. wood, steel castings, and rusty pig iron, it became evident that the nature of the material being ground has an influence upon the behaviour of the primary dust stream in particular. These observations have shown that where a proportion of relatively large particles is produced by the grinding operation, these particles, due to the kinetic emergy imparted to them on their formation and release, follow a straight path tangential to the wheel for a considerable distance (several feet), and that they in turn induce some of the fine dust to follow in the same path and to remain in the primary stream.

The secondary dust stream is brought around with the slipstream produced by the rotating grinding wheel, is discharged into the general atmosphere and may reach the operator's breathing zone. Whether it reaches the operator's breathing zone as a cloud of high concentration depends upon the position of the operator (in particular upon the position of his head), in relation to this stream of dust, and upon the contour of the casting that is being ground. The effect of the shape or contour of the casting being ground is evident, as this secondary stream, on leaving the hood, is directed downwards, and, depending upon the position of the grinding machine relative to the casting will either continue unobstructed until it reaches the floor or will be deflected and spread either sideways and, in many cases, partially upwards, depending upon the configuration of the obstruction, i.e. the casting or bench, which it may meet.

3. *Experimental considerations*

The object of the work described in this paper has been to develop a device or modification that can be applied to new as well as to existing swing frame grinding machines in foundries, preferably involving a minimum cost and a maximum of simplicity.

4. *Stages of development*

In various stages of the experimental work the following alterations to the wheel guard were made

(i) Closing the gap between the sides of the wheel and the hood.

(ii) Closing the opening at the front of the hood with a plate adjustable to the wheel wear.

(iii) Fitting an attachment, which formed an extension to the back of the hood. This extension built in the shape of a box had two intake-openings in the underside. The intake nearest to the wheel (which is an extension of the slot accommodating the grinding wheel) admits the slip-stream that carries the dust forming the secondary dust stream. The second intake was placed further away from the wheel to bring under control the fine dust entrained in the primary stream. Both intakes were provided with sliding covers to allow easy adjustment to the size of the openings.

(iv) Removing a portion of the back plate of the wheel hood, to produce a continuous internal cavity within the original hood and the "box" attachment. The orthodox hood was thus brought within the influence of the exhaust system.

(v) Fitting borizontal flanges to the lower edges of the "box" attachment. These flanges were extended towards the "front" of the wheel and also in the opposite direction beyond No. 2 intake.

Figure 5 shows the design that was finally evolved as a result of the experimental work.

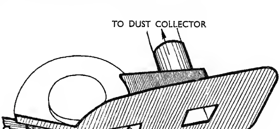

Figure 5. Development Stage 4, showing the position of intakes and the extended flange.

Illustration by courtesy of The British Steel Castings Research Association.

5. CONCLUSIONS

1. A system of dust control, equally applicable to existing or to new swing frame grinding machines has been developed (this system has been protected in the name of the Association by provisional patent No. 35971/53),

2. Extended Dust Research Station trials under varying conditions of grinding have shown that the system provides an effective control of dust, when assessed by the Lawrie illumination technique for airborne dust detection (Plate 19).

3. The system, which is simple in design and relatively cheap to construct, has been shown to be effective when applied to a standard machine with 16 in. dia. grinding wheel operating at a peripheral velocity of 9,000 ft. per min., to which the following modifications were introduced : (Fig. 6).

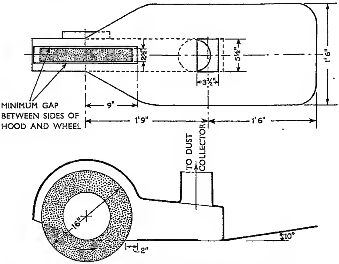

Figure 6. Design of the exhaust hood, showing the sizes and positions of the intakes and the flange.

Illustration by courtesy of the British Steel Castings Research Association.

(a) closing the gaps between the side plates of the hood and the sides of the grinding wheel,

(b) intake No. 1, nearest wheel, should be 2 in. long (with 16 in. dia. wheel fitted),

(c) intake No. 2 should be 3½ in. long by 5½ in. wide and positioned so that its centre line is 1 ft. 9 in. from the centre of the grinding wheel.

(d) the flange should extend from the axis of grinding wheel to a distance 18 in. behind intake No. 2 and should be of a total width of 18 in. so that it projects not less than approximately 6 in. on either side of the side plates of the hood,

(e) the driving belt should be encased.

4. For an effective dust control an exhaust rate 900 cu. ft. per min. at 3¾ in. w.g. static pressure in required.

APPENDIX VII

LOW VOLUME HIGH VELOCITY DUST CONTROL FOR A SWING FRAME GRINDER

1. The development of the low volume high velocity system on portable tools led a foundryman to approach the investigators[24] with the request that it be adapted for use on swing frame grinders. It was evident from the outset that it would use less air than other methods, but it was also clear that the small diameter ducting would have the great advantage of allowing full flexibility to the machine. This is a point of some importance in the operation of swing frame grinders.

2. The wheel guard was fitted[24] with a peripheral duct which had a port in the leading edge (i.e. the edge towards which the wheel face moves as it leaves the point of contact with the metal), a port in the trailing edge and two intermediate ports. This gave reasonably good dust control but the system was greatly improved by an inlet duct fitted with three ports and placed at the leading edge. All the ports were provided with vanes to use the fan effect of the wheel itself. The early experimental work was done in laboratory conditions where it was convenient to induce the vacuum by means of compressed air ejectors (see Figure 4, Appendix III). The prototype machine however was run from a fan which extracted 250 cubic feet of air per minute at a vacuum head of 3 inches of mercury. The port openings were connected to a 3 inch diameter hose which was coupled to the fan.

3. The whole of the development work was based on observations made by the illumination technique and Plate 20—22 are "still" photographs taken from the cinematograph negative[24]. Plate 20 shows the dust cloud produced by grinding a grey iron casting without exhaust ventilation. Plate 22 shows the control achieved by the new system. The wheel is working on the edge of the casting nearest to the operator who is out of the picture on the left. As a result the trailing edge of the guard is over the floor and any dust which leaves the guard is free to flow away. Nevertheless the exhaust system is giving good control at this point. The dust cloud moving from the point of origin towards the leading edge of the guard on the right is under complete control. Here the casting itself is immediately below the exhaust duct, and so has the effect of containing the dust, which cannot easily flow away from the ports in the duct. Plate 21 shows different conditions. The machine has now been swung away from the operator so that the leading edge of the guard, on the right, is over the floor and no physical barrier is present to prevent the dust from flowing away from the ports in the duct. Even in these conditions the new exhaust system completely controls the dust generated by the wheel. It is noticeable that the heavier particles, such as sparks, are also being influenced by the system. Photographs taken when grinding steel and wood showed similar effects.

4. The results of the illumination method were confirmed by dust counts, both on the Owens Jet Counter and on the Thermal Precipitator.[24] The samples were taken when grinding grey iron in laboratory conditions. The tests were not extensive enough to determine the effects of a full day's work in the conditions of a fettling shop, but they showed no increase in dust concentration at the breathing level of the operator during the period they covered. This means that the new system was controlling all the dust that was generated. When taken in conjunction with the observation technique and the photographs, these tests indicated a high level of dust control.

5. The machine is now going for works trials, but the experimental work led the investigators to the conclusion that the dust from a swing frame grinder could be controlled by 250 cubic feet of free air per minute at a vacuum head of 3 inches of mercury, using flexible ducts as small as 3 inches in diameter.

APPENDIX VIII

DUST CONTROL FOR THE PNEUMATIC CHISEL

1. Pneumatic chisels are normally used without dust control of any kind, although if the work is small enough to be dressed on a bench, the bench may be fitted with local exhaust ventilation.[17] Recent work however has resulted in an original approach to the problem.

2. A member of the Committee, and two members of an industrial firm have designed the first integral local exhaust ventilation system to be fitted to a pneumatic chisel.[22] It was obvious that the local exhaust system would have to be an integral part of the tool if it were to be available for heavy work which could not be dressed on a bench. It was equally obvious that the dust control mechanism must be inconspicuous and light, in order to preserve the flexibility and ease of operation of such a hand tool.

It had already been shown that the fine dust from a pneumatic chisel flowed up the chisel shank and followed the line of the operator's arm to rise to his face.[17] This effect is illustrated in Plate 1. Following certain promising mining experiments with a hollow exhausted rock drill it was decided by the investigators to apply to a hollow fettling chisel a similar principle of low volume high velocity exhaust.

3. In the early stages of the work an ordinary pneumatic chisel was used, and a ventilation duct was placed, by hand, over the chisel point. The necessary vacuum was induced by an Eductor as shown in Figure 4, Appendix III. This compressed air ejector was designed to give a static vacuum of 18-20 inches of mercury, and when running at 10 inches of mercury it induced 3.2 cubic feet of free air per minute. The ventilation air was extracted through a $\frac{5}{8}''$ diameter flexible hose at a calculated velocity of the order of 11,500 feet per minute.

The duct control was observed by the Illumination technique and it was decided that it was good enough to warrant the construction of a hollow chisel.

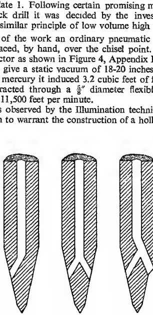

Figure 7. Ducts and Inlet Ports of experimental hollow chisel.

Illustration by courtesy of The Institution of Mechanical Engineers.

4. Experimental hollow chisels were constructed with the duct and inlet port designs shown in Figure 7, and a pneumatic hammer was modified to take a central duct through which the air could be extracted.

5. The development work was done by means of the illumination method and Plates 23—25 which are 'still ' photographs from the original film indicate the results obtained. Plate 23 shows the dust control obtained when using the separate duct held over the chisel by hand and fitted with a fish tail nozzle. Dust can be seen as it moves into the exhaust system. Plates 24 and 25 are a pair taken from the same film negative. Plate 24 shows the hollow chisel before work began, and Plate 25 shows the effect of the new exhaust system on the fine dust generated at the chisel point.

6. A series of dust samples have been taken in laboratory conditions, when using the chisel with and without exhaust.[23] These samples were taken with an Owens Jet Counter, a Konimeter and a Thermal Precipitator. Only one chisel was in use in each case, and the time for which it was used did not allow of any estimate of the accumulated amount of dust which might be expected at the end of a day's work in a full shop using a number of chisels. The dust counts serve however to indicate the efficiency of the system in laboratory conditions. None of the samples was incinerated.

The Owens Jet Counter samples were estimated by the method previously described.[10] This instrument showed the general atmospheric dust concentration as 200 particles per cubic centimetre before starting. Six minutes work with exhaust on the chisel gave a dust concentration at breathing level of 500 particles per cubic centimetere as opposed to 2,700 particles per cubic centimetre produced by seven minutes work without exhaust.

The Konimeter gave no recognisable spot from the atmosphere before starting work. This rose to a dust count of 52 particles per cubic centimetre after six minutes work with exhaust on the Chisel, while seven minutes work without exhaust produced a sample containing too many particles to count.

Similar results were obtained from the Thermal Precipitator samples. The general atmosphere before starting work contained 119—139 particles per cubic centimetre. Working the chisel with the exhaust system gave a sample of 140 particles per cubic centimetre, but an equal time without exhaust lifted the breathing level concentration to 326 particles per cubic centimetre.

The Thermal Precipitator samples were counted to the limit of visibility under light field illumination.

7. The laboratory work on the dust control system has now been completed and the machine is undergoing practical works trials.

8. The laboratory work on the dust control system led the workers to the following conclusions :

(1) It has been confirmed that the fine dust tends to rise from the point of a pneumatic chisel.

(2) Local exhaust ventilation has been applied to a pneumatic chisel.

(3) A low volume high velocity system of local exhaust ventilation has been developed, and it uses, on each chisel, about 4 cubic feet of free air per minute at a vacuum of 10 inches of mercury.

(4) The exhaust can be applied through a separate duct fitted down the side of a conventional chisel.

(5) The exhaust can be applied through a hollow chisel.

(6) The extracted air and the dust is conveyed from the chisel through a central duct fitted in the pneumatic hammer itself.

(7) The exhaust air can be provided by a compressed air ejector or a rotary exhauster.

APPENDIX IX

REQUIREMENTS FOR EFFICIENT DUST SUPPRESSION AT FOUNDRY KNOCK-OUTS

THE BRITISH CAST IRON RESEARCH ASSOCIATION
FOUNDRY VENTILATION AND DUST CONTROL
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Presented on behalf of the
B.C.I.R.A. Foundry Atmospheres Committee
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"This survey of methods of exhausting dust during knock-out operations was originally presented on behalf of the B.C.I.R.A. Foundry Atmospheres Committee by two of its members at a B.C.I.R.A. Conference on Foundry Ventilation and Dust Control at Harrogate in April 1955.[38] It is reprinted from the Proceedings of this Conference."

INTRODUCTION

The design of satisfactory exhaust at knock-outs depends on a variety of factors, mainly comprising :

1. The size and type of casting and mould box.
2. The nature of the moulding sand and its moisture content.
3. The method of handling both the boxes and the castings.
4. The location of the knock-out in relation to the foundry building with its access doorways, windows, etc., and prevailing cross draughts.

In view of the variety of factors governing the exhaust good form, it is impossible to lay down a basis of standard design. Each installation must be considered on its merits, and should be the responsibility of engineers with special experience in this class of work.

With mechanisation it is necessary in most cases for air exhaust to be applied not only to the knock-out, but also to the remainder of the sand handling system, as required, to prevent contamination of the general atmosphere of the foundry from these other sources.

The importance of keeping up the moisture level of all sand on floors, in transit, or subject to vibration cannot be over-emphasized. If the moisture content of the sand is not allowed to fall below about one-half of that normally required for moulding, no dust will be produced by any foundry operation.

FUNDAMENTALS OF HOOD DESIGN

1. To prevent dust from entering the worker's breathing zone, so that although a dust cloud may exist, they will breath wholesome air.
2. The point of exhaust to be as close as possible to the source of dust.
3. Enclosure round source to be as complete as possible.

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In order to achieve the maximum efficiency at minimum cost, the design of hood must take all the foregoing factors into account.

Air outlets can be controlled by mechanical means such as a baffle plate, louvres, etc., but an intake pipe cannot be so controlled. The crudest form of intake, and open-ended pipe, will draw air in from all round, even from behind, but by the addition of the backplate, the inward flow of air is concentrated to the front. (Figs. 8a and 8b).

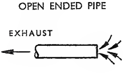

Figure 8a

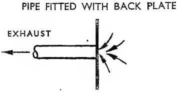

Figure 8b

In designing an efficient hood, the contour of the backplate is of vital importance, as a good design will achieve efficient results with a minimum rate of air extraction. With a bad profile an appreciable increase in the volume of air extracted will be necessary to achieve the same result.

Most knock-outs deal with hot sand, and cause the dust and fume-laden air to rise above the knock-out with appreciable speed. The best extraction efficiency is obtained when this natural flow is used to assist the action of the hood. (Fig. 9).

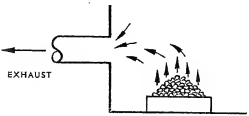

Figure 9

The primary purpose of the hood is to prevent the fine dust and fume from reaching the breathing zone of the workers in the area and to prevent it from spreading into the remainder of the foundry building. The layout of equipment in a foundry should, therefore, be planned so that adequate space is available for an efficient exhaust hood.

When planning new installations, consideration should always be given to locating the knock-out in a separate building or individual enclosure within the main building, in order to simplify the design of the exhaust plant.

In the case of existing installations, the casting handling system adjacent to the knock-out may be such that an efficient hood is precluded. In such a case it may be necessary to alter the handling methods so as to allow the accommodation of an efficient hood.

The proper location of the hood is of first importance, and the method of handling mould boxes, returned empties and castings should, therefore, be planned initially in conjunction with the ventilating Engineer.

METHODS OF EXHAUSTING

1. Fully enclosed knock-out.
2. Side draught.
3. Down draught.
4. Up draught.
5. General ventilation.

1. *Fully enclosed Knock-out.* The fully enclosed system is the ideal method of dust and fume control, as the knock-out is provided with a complete enclosure, with openings on the inlet side for the entry of the moulds, and on the discharge side for the removal of castings and mould boxes. The relatively small area of the openings enables adequate exhaust to be provided with appreciably less air volume than for the other systems described and it is, therefore, considerably cheaper. As in the case of the side draught hood, there is no interference by the exhaust air with the constitution of the moulding sand, and the system is largely protected from the harmful effects of cross draughts in the building. It would appear that this system can be applied on fully mechanised plants, employing standard mould boxes, and on snap flask work. In the past, however, despite its substantial advantages, the system has only been adopted to a limited extent, possibly because difficulties would be encountered in modifying existing plants. The system should be developed in future mechanised plants, but complete enclosure of the knock-out is both mechanically difficult and expensive compared with the other methods of dust and fume control.

2. *Side Draught.* Side draught is effected by means of a hood mounted above floor level and immediately alongside the knock-out point with suction pipe connected to the hood.

The size and position of the suction opening must be governed by individual circumstances, as explained earlier. The suction opening should be mounted in a screen above the level of the top of the mould box, and on the side of the knock-out remote from the operators' working position. In this way the rising dust is drawn to one side of the grid and away from the operators. The top of the hood should be arranged to overhang the knock-out as far as is practicable. The hood should be located close to the edge of the long side of the knock-out and it is not sufficient for the vertical screen to terminate at a height of 2 ft. or 3 ft. above the box. If the knock-out is exposed to cross draughts, the area should be isolated by means of walls or side screens; failing this, an exhaust of greater intensity will be necessary.

The side draught system maintains a constant rate of exhaust unaffected by the presence of large quantities of sand which frequently clog the knock-out grid, and operates directly on the rising column of dust-laden air so that this is drawn continuously away from the operators.

This type of exhaust deals only with the fine dust that is airborne above the moulds, and does not influence the heavier dust and sand which normally falls into the hopper below the knock-out. In this way the exhaust system is not subjected to heavy abrasive wear, which occurs when excessive quantities of sand are extracted; maintenance is therefore reduced, and the initial cost of the installation is less, as it is not necessary to employ such heavy gauge ducting. This system does not extract so large a proportion of the smaller fractions of the sand as does a down draught system.

A criticism often levelled at the side hood system is that it obstructs access to one side of the grid, but this limitation can frequently be overcome.

3. *Down Draught.* Down draught exhaust is effected by extracting air from the hopper or chute below the knock-out, either by nozzles extending along the length or width of the hopper or by shrouded suction openings made in the sides of the hopper. The effectiveness of the down draught system depends on its ability to achieve a complete reversal of the upward flow of the thermal currents generated by the hot sand, moulds and castings before the dust and fumes can reach the breathing zone of the workmen.

(a) Its effectiveness is limited to small castings that produce thermal currents of low velocity and volume, contained in shallow boxes not exceeding 10″ maximum height.

(b) The mould boxes must be standing on the knock-out grid and down draught alone will not be effective when boxes are knocked out when suspended above the grid.

(c) The precise relationship of box size to grid size that can be effectively dealt with will vary both with the shape of the grid and the box, the position of the box on the grid, and the speed of the knock-out, which controls the rate at which the sand falls through the grid.

(d) Moulding boxes should not exceed one-fifth of the total area of the grid on which they rest and through which the down draught air is flowing, so that the falling sand cannot block the grid. This will ensure that the thermal currents rising above the centre of the box will be adequately influenced by the downward air movement.

The overall size of the knock-out grid used in a down draught system should not generally exceed 16 sq. ft. The box must, however, be placed centrally on the grid with ample space all round the box for the downward air flow.

This limitation on the size of the grid, together with the restricted proportion of grid to box area, controls the maximum size of box that can be ventilated by a down draught system.

(e) The sand/metal ratio and the interval of time between pouring and knock-out should together ensure that only the sand adjacent to the casting is dry enough to release dust into the ventilating system.

A down draught ventilating system giving satisfactory control has the following advantages :

(i) The dust and fumes do not rise more than a few inches above the box and control is thus obtained close to the source.

(ii) There is no obstruction to access at floor level.

(iii) It is particularly suitable for highly mechanised foundries producing large numbers of small but uniform light castings.

The principal disadvantages of the down draught system are :

(i) It is restricted to small, light castings in shallow boxes which must be knocked out on a relatively large size grid.

(ii) The extraction of sand produces abrasion and the ventilating equipment requires more maintenance and cleaning than is usual with the side draught system.

(iii) The down draught system is not flexible and if the boxes or other factors exceed the upper limits of the design ratings, dust spillage will occur.

4. *Up Draught.* The up draught system with a canopy hood mounted directly above the knock-out prevents the escaping dust and fume from spreading into the general atmosphere of the foundry and offers no obstruction to access around the knock-out. It does not, however, afford any protection to the knock-out operators, as invariably the dust must travel through their breathing zone before reaching the hood. For this reason, this type of hood does not fulfil the design requirements outlined earlier. The air volume and freedom from interference with the constituents of the sand are comparable with those of the side draught system.

5. *General Ventilation.* In the case of general ventilation, increases in the concentration of dust in the general atmosphere of the foundry building can be limited only by effecting a specified rate of air change, by introducing fresh air at low level, and simultaneously extracting the fume-laden air at high level, and this affords no protection to the men working close to the source of dust. The general ventilation that is sometimes attempted by means of exhaust fans in the roof only is often less effective than the combined system, as a system comprising exhaust only can draw dusty air from other parts of the foundry. General ventilation should only be employed in conjunction with local exhaust applied to each source of dust.

FLOOR MOULDING

When considering the floor moulding of both large and small castings, it is not practicable to apply exhaust close to many of the sources of dust. Every effort must therefore be made to avoid the production of dust. As mentioned earlier, moulding sand will not form dust if the moisture content does not fall below half of that normally required for moulding in green sand, providing that the moisture is evenly distributed throughout the sand. If every effort is made to ensure that the moisture content does not fall below this level, the production of dust will be minimised.

The difficulty most frequently encountered is that hot castings lie in the sand and reduce the moisture content of the adjacent sand below the critical level. Hot castings should, therefore, be removed from the sand as soon as possible to a suitably ventilated cleaning station.

Castings made in dry sand moulds are difficult to treat in this manner. Some form of portable equipment might be considered for use when removing a casting from the mould. The casting should then be transported to a separate section for final cleaning. Any such portable exhaust plant must be arranged to discharge the dust-laden air outside the building.

Efficient exhaust could be most economically achieved by the introduction of one or more central knock-out plants and a sand distribution system, also exhausted as necessary.

When dealing with the floor moulding of large castings a substantial improvement in working conditions is possible if moulding positions can be maintained in lines, each served by the suction main of an exhaust system, to which flexible branch pipes could be temporarily attached adjacent to the moulding pit where work is in progress. This pit can be temporarily protected by the use of portable screens and hoods used in conjunction with the flexible suction pipe. The hood and pipe positions can also be easily moved to suit the progress of the work, thus affording protection to workers in the immediate vicinity, and reducing the spread of dust into the foundry building. The portable equipment can be easily moved from one pit to another.

The main suction ducts will need to be accommodated so that they do not interfere with the use of gantry cranes, and may either be underground or carried from the main building stanchions.

The alternative system comprises the use of underground ducts to the permanent moulding pits. With this system, the exhaust must be applied continuously to all the pits, whatever the stage of the work, and this requires a large and costly installation. An independent system for each pit must otherwise be envisaged.

SUMMARY OF DUST CONTROL REQUIREMENTS

1. The most effective dust control is provided by complete enclosure of the knock-out.

2. In side draught systems a long side of the knock-out should be made available for the hood with sufficient space for an efficient form of hood. The side draught system is particularly flexible and suitable for less highly specialised foundries. In some circumstances hopper exhaust can be used with advantage to supplement side draught.

3. Up draught systems carry the whole of the extracted dust past the breathing zone of the operator, and can only offer protection if the operator is in such a position that replacement air diverts the stream away from his breathing zone.

4. Down draught systems can give satisfactory protection from dust and fumes produced by small castings in shallow boxes under the special conditions indicated.

5. General ventilation can do no more than keep down the dust and fume concentration in the foundry, and affords little protection to the knock-out operator.

6. Ventilation must not be an afterthought. It is part of the basic lay-out, and the plant designer must be prepared to co-operate with the ventilation engineer at an early stage, and to incorporate his recommendations in the plant arrangements.

7. If the moisture level of sand is kept at or above approximately one half that required for moulding it will not produce dust in any foundry operation.

APPENDIX X

THE WET DECORING BAR

1. A member of the staff of the British Cast Iron Research Association has designed a bar for wet decoring.[30] An ordinary bar has been fitted with a ring which carried four jets from which a fine spray of water can be projected beyond the point of the bar (see Plate 26). When the bar is in use the water spray reaches the core before the point of the bar strikes it, so that the core sand is wetted before being dislodged. This is therefore an attempt to eliminate dust at source, and not a dust control method because the moist sand will be dust free even when it is knocked out of the casting by the bar.

2. The device was examined by means of the illumination technique and proved eminently successful on the cores on which it was used.[30] Plate 27 shows conditions before commencing work. No dust is visible in this photograph. Plate 28 shows the wet bar in use while Plate 29 shows conditions when the work had been finished. It will be seen that the operation of decoring with the new bar produced no visible dust in the optical conditions imposed,[30] and that the atmosphere was just as free of airborne dust at the end as it was at the start. Plate 30 shows conditions two minutes after finishing work with an ordinary bar when the operation had been done dry. The airborne dust cloud which had been raised is still clearly visible in this photograph.

3. A short series of dust counts was also taken during the experimental work on the process.[30] The Owens Jet Counter and the Thermal Precipitator were used, and the samples, which were taken at the breathing level, were not incinerated. The results confirmed the observations made by the illumination technique.

The Owens Jet samples were estimated [10] and gave a general atmosphere dust concentration of about 1,000 particles per cubic centimetre before starting work. This remained constant during the wet decoring, but rose to 3,600 particles per cubic centimetre after dry decoring. This sample was taken 2 minutes after dry decoring had ceased, so that heavy dust would have had time to fall out of the atmosphere.

The Thermal Precipitator samples were counted under light field illumination to the limit of visibility. This instrument showed a dust concentration of 869 particles per cubic centimetre before starting work, with a concentration of 924 particles per cubic centimetre after wet decoring. Dry decoring, by the old method, gave a corresponding dust concentration of 6,980 particles per cubic centimetre at the end of the process.

The decoring bar is now in use in a dressing shop. The preliminary experimental work, however, resulted in the following conclusions :

(1) A fine water spray, projected beyond the point of a decoring bar, proved sufficient in the cases investigated, to wet the sand of the core before it was struck by the bar. In consequence no dust was raised during the decoring operation.

(2) The device would use not more than 20 gallons of water per hour, with the four jets operating continuously. The water is only needed intermittently, and it has been found in practice that the maximum quantity required does not exceed 10 gallons per hour.

APPENDIX XI

CARBON MONOXIDE FROM THE CUPOLA

1. The British Cast Iron Research Association sampled the air around the base of a cupola in this country and found up to 0.08% carbon monoxide after eight hours running. If the base of this cupola had been confined this might well have proved a serious hazard. As a result of this preliminary investigation the Association explored the matter more thoroughly,[32] and showed that carbon monoxide could leak from a cuploa in a variety of conditions. A summary of the work was published in 1954.[33]

2. The risk on the charging platform of the cupola is caused by gas leaking from the charging doors. The author of the paper published by the British Cast Iron Research Association[33] concluded that the following conditions can cause such a blowback of gas :

(1) Restriction in the stack above the charging door.

(2) Restriction caused by the fitting of spark arresters of any type.

(3) Terminating the cuploa stack below the ridge of the roof or below the lift hoist shaft.

(4) The use of bucket charging devices which momentarily interrupt the flow of gas from the top of the charge to the cupola stack.

(5) Direction of wind.

The degree of risk associated with gas leakage will of course very with local conditions, but the matter warrants serious attention if the platform is totally enclosed, and especially if the air on the platform is contained within the general ventilating system of the foundry.

3. It was also pointed out as a result of the investigations[33] that the effect of spark arresters might be important if their resistance is high, and that this may be particularly dangerous if two cupolas discharge into one arrester. In these circumstances there is a possibility, if the foundry building is under slight vacuum from its ventilating system, that gas from the cupola which is operating may be drawn down the stack of the adjacent cold cupola. It is unnecessary to stress the danger that might so result if men were working inside the cold cupola, and in any case the gas might well pass into the foundry building itself.

4. Many foundries have powerful ventilating systems and in consequence there is often a reduction in air pressure inside the building. Quite apart from the ventilating system, wind effects may produce negative pressures inside buildings.[33] [34] These effects may exert considerable influence on the distribution of leaking gas inside the building and they should always be considered in cases where any gas leakage has been found from any source.

5. The work of the British Cast Iron Research Association did not result in the establishment of specific conditions which would always prevent any gas leakage, but it was sufficient to enable the author of the published work[33] to state that "where the following conditions have been met, no leakage has been found to take place.

(1) The stack above the charging door should be the full diameter at charging sill level.

(2) The stack height above the charging door should be approximately 7 times the diameter at the charging door.

(3) The free area at any point of restriction or change of direction should be not less than 3—4 times that of the lined diameter at the charging door.

The last recommendation is likely to be more significant where wet spark arresters are employed, since there may be some restriction to flow by the curtain of water."

APPENDIX XII

RECOMMENDATIONS FROM REPORT ON THE DRYING OF MOULDS BY PORTABLE DRYERS

1. No ordinary open fire should be used for mould drying other than in exceptional cases where it can be shown to be unavoidable.

2. Hard cupola coke is the most suitable fuel whilst hard furnace coke is also suitable. Gas coke is less satisfactory.

3. The coke should be graded and the size should not be less than 1½″. The size range from 2″ to 3″, when free from fines, gives the best results.

4. Gas coke in the size range less than 1″ is definitely unsuitable and should not be used.

5. Manufacturers of mould dryers should ensure that the depth of the fuel bed is not such as to produce excessive carbon monoxide in the products of combustion.

6. Coke should be charged frequently and in small quantities, or alternatively a controlled feeding device should be employed.

7. Manufacturers should ensure that the fan will overcome the resistance of the dryer and the mould.

8. The fan should supply a sufficient volume of air to the dryer.

9. Valves should be simple in operation.

10. Valves should be designed so that they remain operative in spite of dirt and rough handling.

11. Where separate valves control the primary and secondary air it should not be possible to shut off the secondry air completely.

12. The grate should be designed to allow of easy clinkering and cleaning.

13. The grate of the dryer should be kept clean and clinker or ash should not be allowed to accumulate on it.

14. Mould dryers should be used in such a fashion that there is as little restriction as possible between the dryer outlet and the mould outlet.

15. The end of the main discharge pipe from the dryer should be not less than 1½ times the pipe diameter from the nearest protection plate or mould surface.

16. The total area of the discharge openings from the mould should be not less than 1½ times the area of the dryer discharge pipe. If this cannot be ensured by the use of the runners and risers, or by wedging up the cope, then a "lift out" piece should be provided to give the required area.

17. The cross sectional area of any ducting between the dryer and the mould should be not less than the cross sectional area of the dryer outlet.

18. If bends are included in any ducting between dryer and mould they should be of the full duct diameter and round rather than abrupt; it should not be forgotten that a right angle bend reduces the effective cross sectional area of the pipe to seven tenths its original area, so that pipe diameters should be correspondingly increased as the angle between the arms of the bend decreases.

19. A CO/CO_2 ratio of not more than 0.05 should be obtained within 5 minutes of recharging the dryer with cold coke.

20. A CO/CO_2 ratio of not more than 0.02 should be obtained within 10 minutes of recharging the dryer with cold coke.

21. These ratios should be obtained when the heater is working at the makers stated rate, and discharging against a back pressure of 1" water gauge in the discharge pipe.

22. Low sulphur coke should be used to minimise the production of sulphur dioxide.

23. When controlling the temperature of the exit gases by adjusting the valves, the combustion rate should be high enough to maintain a brightly incandescent fuel bed.

24. The mechanical design should be simple, so that even after much use or neglect, the dryer will function correctly.

25. The dryer should be designed so that it can be lifted in safety.

26. Initial lighting of the dryer should be safe and simple.

27. Wherever possible an initial charge of brightly burning coke should be used to avoid smoke, and the fuel bed should be built up gradually to the recommended height.

28. Wide fluctuations in the proportions of fuel and air should be avoided.

29. Mould dryers should not be used in confined, unventilated spaces.

30. When the discharging gases from a mould escape through a single opening it is probably worth while fitting a short pipe to the opening so that the gas discharge will be above breathing level.

31. Manufacturers should issue clear and simple instructions on the use of dryers and these instructions should be readily available to operators. This might be achieved by affixing instruction plates to all dryers. Strict compliance should be maintained with the makers' instructions when using dryers.

APPENDIX XIII

FUMES IN FOUNDRY ATMOSPHERES

A short survey of some relevant work published since 1949.

by W. M. LORD, B.Sc. Tech., A.I.M.

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Summary

Fumes are produced during the course of foundry operations by the incomplete combustion or destructive distillation of organic substances added to moulding and core sands to confer " bond " and other desirable working properties. The most important of these materials are pulverised coal, linseed and drying oils, dextrines and synthetic resins of the urea formaldehyde and phenol formaldehyde types. Other materials such as pelleted pitch, sulphite cellulose lye, etc. are occasionally used.

The whole subject of clean air in foundries is becoming increasingly important, in view of the growing public consciousness about the undesirable effects of 'smog' and smoke in the outside air. Some data from recent papers on general atmospheric pollution are included in the present review.

Introduction

Since the publication of the author's original report[2] on the fumes produced from various core bonding materials, a number of interesting papers have appeared amongst which, one by Horspool, Julian and Oldham[43] is important. These workers examined the composition of the gaseous thermal decomposition products from cores bonded with 2% of linseed oil, within the temperature range 400°—800°C. They found that the least volume of gas containing the highest proportion of carbon dioxide was obtained from sample cores baked for one hour at 230°C. Under certain conditions liquid products were obtained in small quantity but this distillate was not examined. Roesch[44] has described an apparatus and technique employed to measure the amounts of gas given off by different moulds.

Foundry Atmospheric Pollution arising from the use of Coal Dust

Much public interest is being taken in general atmospheric pollution and the ill effects produced by coal combustion products. The Minister of Housing and Local Government announced in the House of Commons on 20th October, 1953 that an Air Pollution Committee had been appointed, while the organisation for European Economic Co-operation[45] has arranged for a Technical Assistance Mission to visit a number of European countries to study methods of dealing with air and water pollution caused by the Chemical Industries.

Since coal dust is an accepted ingredient of sand mixtures used for the production of iron castings by green sand methods, the problem of combustion products from coal which are released into the foundry atmosphere after casting must be considered of great importance. Meetham[46] investigated the size distribution of smoke particles at Teddington (a non-industrial area) and found that half the number of particles were less than 0.075 micron in diameter. Professor Clemo[47] collected a quantity of "smoke" from the atmosphere of Newcastle in two large filters, through which an average of 424×10^6 cubic feet of air had been passed.

Benzene extraction of the filters gave 1—3 grams of dark material 'A' which was not examined. Petroleum extraction (B.P. 60°—80°C.) gave an amorphous material 'B' weighing approximately 2.25 grams and an amber coloured resin 'C' weighing 4.75 grams. Chromatographic separation of material 'C' gave the following fractions.

C1. Colourless material of the C_{30} paraffin range (M.P. 68°C ; Found C=84.8% H=14.8%).

C2. A yellow oil containing probably diethylpyrene and dimethlychrysene.

C3. A number of other products which have not been examined.

Cooper and Lindsey[48] in a series of short notes refer to their own work and reports by other workers of the presence of a variety of substances which are present in atmospheric soot, some of which appear to be of a dangerous nature.

The following substances* were found to be present "quite definitely."

Benzpyrene
Anthracene
Pyrene
1 : 2 Benzpyrene
3 : 4 Benzpyrene
Perylene
1 : 12 Benzperylene
Fluoranthene
Anthanthrene
Alkylpyrenes

The same workers[49] also found anthracene and 3 : 4 benzpyrene and small amounts of other substances in cigarette smoke. Cooper and Lindsey[50] discussing the existence of polycyclic hydrocarbons in the atmosphere say "We also have the opinion that these compounds originate from a number of sources other than the combustion or carbonisation of coal. This is supported by the analysis of exhaust gases from internal combustion engines, and an analysis of products of the high temperature combustion of other materials."

In the absence of evidence to the contrary all organic sand binders, as well as coal dust, must be considered as potential producers of undesirable pyrolysis products. Much further work will be required to ascertain whether any particular material should be employed in the foundry, or not.

The subject of foundry atmospheric pollution has received considerable attention in America and a code of Foundry Safety Practices[51] has been issued in which precautions are suggested against acrolein vapour (from acrolein drying oils) coal dust and many other materials and metals.

Such procedures, whilst sound in principle are not true solutions to the problem of foundry atmospheric pollution. This can only be achieved by development of new methods of mould making in which the mould refractory does not require to be mixed with organic substances. Whether or not this will be possible is not yet known but the development of the sodium silicate-carbon dioxide process is a step in the direction of this very desirable goal.

Todmorden, April, 1955.

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* For further data concerning these substances, the following books may be consulted :—

Dictionary of Organic Compounds. Heilbron and Bunbury. 4v. London, 1943/1944.

The Higher Coal Tar Hydrocarbons. Everest, A. E. Longmans. London, 1927.

Appendix XIV

Recommendations from Technical Report on Practical Methods of Reducing the amount of fumes from Oil Bonded Cores

General

1. Attention should always be given to the technical control of operations in all core shops.

2. The importance of the mixing operations should not be underestimated.

3. A high standard of good housekeeping should be maintained in the core shop and in the core sand mixing plant.

4. The number of mixtures used should be reduced to a minimum.

5. All operators should be provided with full and clear instructions.

6. The extravagant use of binders should be avoided.

7. The Core Binder suppliers should be consulted in the choice and use of binders.

Storage of Core Binders

8. Proper storage should be provided for binders and, in particular, extremes of temperature should be avoided ; also in the case of powders dampness should be avoided. Old stocks should be used first.

Sand

9. Careful consideration should always be given to the grade of sand to be used, which should be selected with regard to the properties which will be required of it.

10. The proportion of clay and other fines should be restricted to the minimum needed for the work.

Sand Temperature

11. Sand should be cooled before mixing.

Mixing

12. All mixtures should be made on the basis of weight.

13. Semi-solid additions should be weighed.

14. Full details of each mixture should be determined.

15. Strict control should be exercised to ensure that there is no deviation from the specified mixture.

Storage of Mixed Sand

16. Proper storage should be provided for mixed core sand to ensure conditions which reduce to the lowest possible level the rate of evaporation of the moisture.

Baking

17. Cores should not be used in an underbaked condition.

18. The most satisfactory baking cycle should be ascertained and subsequently followed rigidly.

19. So far as is possible cores of a similar size should be baked together.

20. Every effort should be made to avoid the constant opening and shutting of hatch stove doors.

21. Fuming cores should be cooled either in the cooling chamber of the stove or under a hood provided with efficient exhaust ventilation.

22. Efficient stoves provided with means for recording and controlling temperature should be used.

23. Stoves should not be heated by an ordinary open fire.

24. Adequate and suitable flue systems should be fitted to all stoves to ensure that the fumes from the stoves do not enter the foundry or core shop.

Casting

25. All vents should be lighted after casting.

Types of Cores

26. "Shell" cores should be used wherever possible to replace large solid cores.

Core Block Moulding

27. The minimum possible quantity of binder should be used.

28. Moulds should be cast under a hood fitted with efficient local exhaust ventilation.

APPENDIX XV

FOUNDRY ATMOSPHERES COMMITTEE

The Collection and Examination of Volatile Decomposition Products from Moulds, Cores and Bonding Materials

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Summary

The production of fumes and vapours from foundry moulds and cores continues to cause speculation about their composition and possible toxic nature and various techniques have been described[52] which are applicable to the sampling of fume laden air.

A simple laboratory method has been devised to simulate foundry conditions as far as possible, whilst allowing the volatile substances to be collected for chemical examination and a note is included on the pyrolysis of maize dextrine.

In view of the literature[2] already published, some attempts of this kind have been mentioned, but few workers have paid much attention to the composition of the complex oils and tars which are obtained. The difficult chemical work involved in analysis of this kind has been made a little easier by modern techniques of chromatography and absorbtion spectrophotometry.

Introduction

The work to be described gives information on some of the breakdown products of maize dextrine dry distilled at 800°C in a stream of Nitrogen, as well as a simple method of collecting fumes from iron foundry moulding sand. When a green sand mould is filled with molten iron the sand layers adjacent to the liquid metal are rapidly raised to the metal temperature whilst the sand further away from the interface attains progressively lower temperatures towards the outer surface of the mould. Volatile products consisting of permanent gases and tarry liquids are produced in the hot zones of sand and these products pass through increasingly cooler layers before making their exit from the mould surface. The composition of the gases and vapours obtained from a mould is an average of the compositions which would be obtained by heating the sand mixture at any temperature between that of the molton metal and atmospheric temperature.

Experiments made at only one or even a series of temperatures do not give a true indication of the varied composition of the volatile products. Nevertheless, the experiments described in this note using dextrine were carried out at one temperature only, namely 800°C.

PART I

Fumes from Green Sand Moulds

A simple apparatus was assembled which would produce results corresponding to those expected from an actual cast mould, i.e. an apparatus in which the source of heat was in the centre of the sand mass. Several workers have described experiments in which the mould was actually filled with molten metal in the usual way but this procedure was rejected in the present instance as being inconvenient and likely to result in damage to glass apparatus. A method was required which could be operated at any time in the laboratory, designed to yield reasonably accurate results and avoid unnecessary complications.

After careful consideration it was decided to examine the volatile products produced from green sand moulds rather than from cores. Our reason for this decision was that much more moulding sand, containing coal dust in addition to other normal ingredients is employed every day in foundries, than core sand mixtures. The method of test can be used for core sand mixtures. In all probability, the bulk of the atmospheric pollution in iron foundries, excluding dust from knock-outs and fettling operations, arises from this source. The experiments collected liquid and tarry materials and no attempt was made to collect or measure the volumes of permanent gases which were produced at the same time.

Apparatus

After a number of unsuccessful trials, an apparatus (Fig. 10) was assembled in which a quantity of prepared moulding sand was rapidly heated to a temperature about 1250°C by means of silicon carbide (Silit)* rods contained in combustion tubes which were embedded in the sand mass. The combustion tubes were found to be essential to prevent short circuits through the damp sand. In simulating dry sand or baked core sand practice, the Silit rods could be embedded directly in the sand and baked in the oven along with the sand. The four Silit rods employed in this experiment were calculated to heat surrounding sand "mould" at approximately the same rate and to the same temperature as would have been the case had molten iron of volume 6 cub. ins. been poured into it.

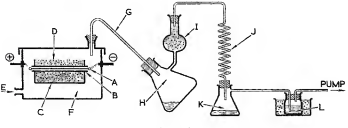

Figure 10

A = Silit Rods[4]
B = Combustion Tube
C = 'Moulding Box'
D = Sand mixture under test
E = Air Inlet
F = Container with loose lid
G = Air Condenser
H = Receiver—Product A
I = Trap packed with glass wool—Product C
J = Secondary Air Condenser
K = Secondary Receiver—Product B
L = Bubbler containing 2 : 4 dinitrophenylhydrazine solution—Product D

The sand mass, containing the combustion tubes and Silit rods was contained in a metal box representing the moulding box (see Fig. 10) and the whole of this unit was placed in another metal box with a loosely fitted but gas tight lid. The secondary box was provided with an air inlet and gas outlet. The whole of the "atmosphere" inside the secondary box was drawn through a condensation system by means of a suction pump. The liquid products were condensed and collected in the several receivers. The final bubbler contained a solution of 2 : 4—Dinitrophenylhydrazine (0.5%) in solution in 5% sulphuric acid. This substance reacts readily with aldehydes and ketones giving yellow to red precipitates. The bubbler was cooled in ice.

* Siemens-Schuchert. Ref. P75105.

The actual temperature of the sand mixture was measured with a Pt/Pt-Rh thermocouple and its position relative to the four combustion tubes is shown in Fig. 11.

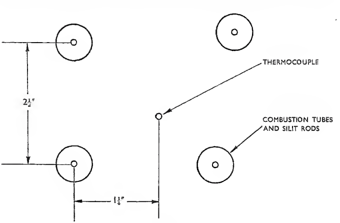

Figure 11

Sand Mixture

A synthetic sand mixture was made up in a laboratory mill from the following materials :

Hensall Sand (as received)	equal parts by weight
Congleton Silica (as received)	
Coal Dust	4%
Bentonite	1%
Water	as required.

Milled for 5 minutes.

Typical test results on this mixture were :

Water	6.5%
P.N.	66

Green compression 5.2 lbs. per sq. in.

Experimental Procedure

Nine runs were made with the apparatus as described using 8 lbs. of sand for each test. Some of the first runs resulted in violent explosions, the force of which was relieved by the loose fitting lid on the atmosphere chamber. Water and tar collected in the receivers. A red precipitate appeared in the final bubbler. The temperature recorded by the couple was 1250°C. A typical run proceeded as follows :—

Water pump suction is applied at maximum and the full current switched on. In about 1 minute fumes are seen in the condenser and shortly afterwards, a clear watery liquid begins to distil. The temperature shown by the thermocouple rises very slowly at first and takes at least 5 minutes to show 100°C and 10 minutes to show 200°C. The distillate becomes very tarry and fumes begin to be evolved more quickly than they can be pulled through the apparatus, and so there is a leakage of smoke from the furnace box. Occasionally, there is a slight 'pop', just sufficient, on some occasions, to disturb the lid of the furnace box. With the latest set-up, this was never a serious explosion. After about 400°C the temperature rises more quickly, and the fume evolution soon reaches a peak and declines sharply. At 1250°C the current is switched off, and a few minutes later air is discontinued. The furnace takes a long time to cool and usually the following day is dismantled and recharged. The method was "heavy" on combustion tubing which became very brittle after using only a few times. The temperature near the rods must have been very much in excess of 1250°C.

The sand near the combustion tubes was white and partially fused. The remainder was black, the coal appears to be fully carbonised. Near any opening into the furnace the carbon had completely burnt and the sand was brownish-red.

The products collected in the receivers and trap, H. I. K. were collected separately but the resulting material from the nine runs was combined. The red precipitate was filtered off and dried.

Examination of Products

1. Tarry material. This has not yet been examined.
2. The aqueous liquor from receiver H contained 0.33% of free and combined ammonia (Method described by Scott—Standard Methods of Chemical Analysis—5th Edn. Vol. 1, p. 637).
3. The aqueous liquor gave an acid reaction to litmus.
4. An orange-red precipitate was obtained from the final bubbler L.
5. The aqueous liquor gave an immediate yellow precipitate with a solution of 2 : 4—dinitrophenylhydrazine, indicating the presence of aldehydes and ketones. Towns gas also gave a precipitate under the same conditions. M.P. 85°C.
6. The aqueous liquor gave a transient violet colour with ferric chloride solution.

The full chemical examination of these products or others which may be obtained from core sand binders under similar conditions is likely to be a time absorbing procedure and require specialised ability and equipment which is probably not available within the foundry industry. For example, techniques are available for the detection and determination of polynuclear hydrocarbons in microgramme quantities[53]

A number of papers have been published on the identification of specific aldehydes and ketones by means of 2 : 4—dinitrophenylhydrazine.[54]

PART II

A note on the Pyrolysis of Maize Dextrine at 800°C

This note describes some exploratory work on the composition of fumes from maize dextrine, dry distilled at 800°C in a stream of nitrogen.

It was decided to use dry maize dextrine (G.B. Kordek) in all preliminary trials, instead of baked cores, as it was considered that the use of cores in the initial experiments would introduce too many uncontrollable variables into the procedure (e.g. degree of preliminary carbonisation from inside to outside of core, effect of air during baking). The fumes obtained in the experiments may be reasonably assumed to represent those produced during the baking process and the casting process (from those parts of the mould or core which do not exceed 800°C).

Apparatus

The dextrine was distilled in a stream of pure dry nitrogen and heat was applied with the aid of an electrically controlled tube furnace. The general set-up of the apparatus was similar to that of the Institute of British Foundrymen Sub Committee TS.13[2]. A boat containing 1 gram of dry dextrine was introduced into the previously heated furnace at 800°C±5°C by means of a solenoid, the dry nitrogen passing meanwhile. Almost immediately there was evolved a rapid stream of fumes and gases. The initial surge made the condensation or collection of these products very difficult.

After many trials a glass column was used of 1.2 cm. diameter and some 140 cm. long. This was attached through a filter flask to the outlet end of the combustion tube and clamped in a vertical position. It was filled to a height of 130 cms. with Fenske glass helices. The top of the column was fitted with a dropping funnel and an outlet tube connected to two boiling tubes in series. These acted as guard tubes and contained the same liquid as used in the column.

By a suitable technique the column could be kept full of liquid while the gas was passing. Traces of acid vapours were trapped in the guard tubes. In spite of these, however, some fume was noted at the exit of the second guard tube during each run, this indicated the presence of a proportion of extremely finely dispersed particles.

Procedure

Three liquids were tested as absorbents in the column.

(a) N/10 Caustic Soda Solution.
(b) Redistilled Chlorobenzene (B.P.130°—132°).
(c) Water.

(a) In the case of caustic soda solution the solutions from the column and guard tubes were titrated separately with N/10 acid. In each case no alkali had been neutralised in the guard tube. The acid products of the distillation calculated as acetic acid amounted to 4.26.% Bantlin[2] obtained 5.29% acetic acid from a sample of starch distilled at 500°C.

(b) The experimental procedure using chlorobenzene was the same as described above. The liquid at first colourless became pale yellow in colour and acquired a very pungent odour. It was not possible to separate this liquid by simple fractional distillation. The pungent odour was much reduced in the distillate and residue. It was concluded that the odiferous substances were present in very small amount and may have decomposed during distillation. Further work is required to isolate the substance(s) responsible for the pungent smell.

A sample of the original chlorobenzene solution (i.e. before distillation) was extracted with water and the solution tested qualitatively for various groups of compounds. The following were identified—Acids, ketones, aliphatic aldehydes or acetals, aromatic aldehydes, ketones or furfuraldehydes. The presence of formaldehyde was suspected and unsaturated compounds were present as indicated by the rapid decolourisation of bromine water and potassium permanganate solution. Phenol compounds were absent. The acids present were further identified by the method of Middleton[55] and in this way formic, acetic, propionic and unsaturated acids were found to be present.

(c) When water alone was used in the column and the resulting solution examined as before, the following substances were identified, formic, acetic and propionic acids, esters, unsaturated compounds, formaldehyde, propionaldehyde and furfuraldehydes.

Residue

The carbonised residue in the combustion boat was weighed and an average of ten determinations gave 5.80%. No attempts have been made to identify the permanent gases produced during the distillation.

Summary

Preliminary experiments on the carbonisation of maize dextrine at 800°C in an atmosphere of nitrogen have been made, and a method for collecting some of the volatile products has been devised. In the liquid portion of the distillate, formic, acetic and propionic acids have been identified together with esters, unsaturated compounds, formaldehyde, propionaldehyde and furfuraldehyde.

APPENDIX XVI

IRON FOUNDRY ACCIDENTS, 1953

GENERAL SUMMARY

1.	Power Driven Machinery (Excepting Hoisting Appliances)		300
2.	Hoisting Appliances		285 (2F)
3.	Falls of Persons		394 (1F)
4.	Burns		
	(a) Molten Metal	721 (2F)	946 (2F)
	(b) Others	225	
5.	Eye Accidents		
	(a) Molten Metal	170	475
	(b) Others	305	
6.	Hand Tools		206
7.	Handling Material		1,962
8.	Falling Articles		
	(a) Foot Injuries	878	1,198 (3F)
	(b) Others	320 (3F)	
9.	Stepping on ; Striking Against		293
10.	Electrical		11 (1F)
11.	Transport		104 (1F)
12.	Miscellaneous		58
		TOTAL	6,232 (10F)

IRON FOUNDRY ACCIDENTS, 1953.

1.	POWER DRIVEN MACHINERY (Except Hoisting Appliances)		
(a)	Grinding Machines (Including Portable Wheels)		119
	(i) Burst Wheels	14	
	(ii) Contact with Wheel	86	
	(iii) Others	19	
(b)	Sand Plant		27
	(i) Mills	17	
	(ii) Conveyors	6	
	(iii) Others	4	
(c)	Conveyors		24
(d)	Moulding Machines		45
(e)	Core Machines		23
(f)	Portable Machines and Tools		16
(g)	Prime Movers and Transmission Machinery		1
(h)	Pattern Making Machines		26
(k)	Miscellaneous		19
		TOTAL	300

2.	HOISTING APPLIANCES		
(a)	Hoists		7
(b)	Cranes, Winches, etc.		32 (1F)
(c)	Failure of Tackle		5
(d)	Slinging Accidents		225
	(i) Slipping or Falling Load	90	
	(ii) Struck by Moving Load or Sling	53	
	(iii) Injured while Handling Load	65	
	(iv) Articles Dislodged by Crane	12	
	(v) Other	5	
(e)	Balling Castings		6 (1F)
(f)	Others		10
		TOTAL	285 (2F)

3.	FALLS OF PERSONS		
(*a*)	From Heights		85
(*b*)	Into Holes		31
(*c*)	On the Flat		211
	(i) Tripping over Loose Objects	93	
	(ii) Slipping	57	
	(iii) Others	61	
(*d*)	On Stairways		31
(*e*)	From Ladders		36 (1F)
		TOTAL	394 (1F)

4.	BURNS		
(*a*)	Molten Metal		721 (2F)
	(i) At Cupolas, Furnaces, etc.	117 (1F)	
	(ii) Transporting	181	
	(iii) Casting	355 (1F)	
	(iv) Casting Machines	8	
	(v) Miscellaneous	60	
(*b*)	Explosions (including blow-backs)		31
(*c*)	Fires		12
(*d*)	Welding		13
(*e*)	Other Hot Substances		143
	(i) Castings and Other Metal	60	
	(ii) Sand	68	
	(iii) Others	15	
(*f*)	Scalds		13
(*g*)	Others		13
		TOTAL	946 (2F)

3.	FALLS OF PERSONS		
(*a*)	From Heights		85
(*b*)	Into Holes		31
(*c*)	On the Flat		
	(i) Tripping over Loose Objects	93	211
	(ii) Slipping	57	
	(iii) Others	61	
(*d*)	On Stairways		31
(*e*)	From Ladders		36 (1F)
		TOTAL	394 (1F)

4.	BURNS		
(*a*)	Molten Metal		
	(i) At Cupolas, Furnaces, etc.	117 (1F)	721 (2F)
	(ii) Transporting	181	
	(iii) Casting	355 (1F)	
	(iv) Casting Machines	8	
	(v) Miscellaneous	60	
(*b*)	Explosions (including blow-backs)		31
(*c*)	Fires		12
(*d*)	Welding		13
(*e*)	Other Hot Substances		
	(i) Castings and Other Metal	60	143
	(ii) Sand	68	
	(iii) Others	15	
(*f*)	Scalds		13
(*g*)	Others		13
		TOTAL	946 (2F)

8.	FALLING ARTICLES		
(*a*)	Bad Stacking		
	(i) Foot Injuries	47	73 (1F)
	(ii) Others	26 (1F)	
(*b*)	Articles Dropped or Dislodged while Handling		
	(i) Foot Injuries	721	926
	(ii) Others	205	
(*c*)	Others		
	(i) Foot Injuries	110	199 (2F)
	(ii) Others	89 (2F)	
		TOTAL	1,198 (3F)

9.	STEPPING ON : STRIKING AGAINST		
(*a*)	Stepping on Loose Objects		
	(i) Cuts and Abrasions	33	114
	(ii) Sprains	54	
	(iii) Knocks, etc.	27	
(*b*)	Kneeling on Objects hidden in Sand		16
(*c*)	Slippery Surfaces		48
(*d*)	Collisions		97
(*e*)	Miscellaneous		18
		TOTAL	293

10.	ELECTRICAL		
(*a*)	Trolley Wires and Conductor Rails		2
(*b*)	Other Exposed Conductors		3
(*c*)	Faulty Insulation		4 (1F)
(*d*)	Others		2
		TOTAL	11 (1F)

11.	TRANSPORT		
(*a*)	Railway Locos. and Wagons		18 (1F)
	(i) In Motion	9 (1F)	
	(ii) Stationary	9	
(*b*)	Lorries, Power Driven Trucks, etc.		62
	(i) Collisions between two Vehicles	3	
	(ii) Collisions between Vehicle and Stationary Object	6	
	(iii) Persons Struck by Vehicle	11	
	(iv) Persons trapped between Vehicle and Fixed Object	21	
	(v) Starting Handles	11	
	(vi) Others	10	
(*c*)	Other Vehicles		24
		TOTAL	104 (1F)

12.	MISCELLANEOUS		58
		GRAND TOTAL	6,232 (10F)

APPENDIX XVII

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Plate 1. Fine dust cloud rising from Pneumatic Chisel. No exhaust ventilation in use.

Photograph by courtesy of The Institute of British Foundrymen

Plate 2. Dust stream flowing from hood of stand grinder. Conventional local exhaust ventilation fitted and operating.

Photograph by courtesy of The Institute of British Foundrymen.

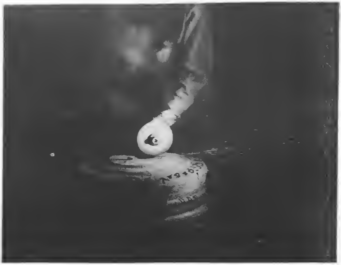

Plate 3. Dust cloud generated by Portable Abrasive Wheel.
No local exhaust ventilation in use.
Photograph by courtesy of The Institute of British Foundrymen.

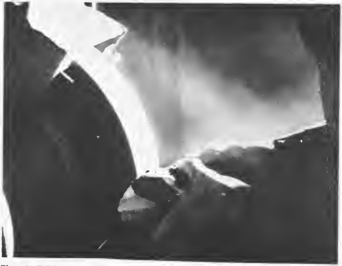

Plate 4. Primary dust stream flowing from hood with conventional local exhaust system fitted and operating—14″ diameter wheel.
Photograph by courtesy of The Institute of British Foundrymen.

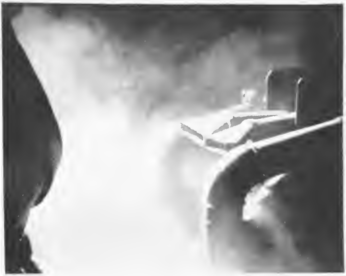

Plate 5. Grinding grey iron without local exhaust ventilation.
Photograph by courtesy of The Institute of British Foundrymen.

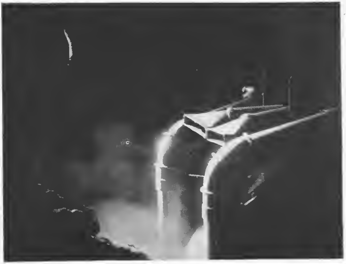

Plate 6. The external system with the exhaust fully operative. Dust control when grinding grey iron.
Photograph by courtesy of The Institute of British Foundrymen.

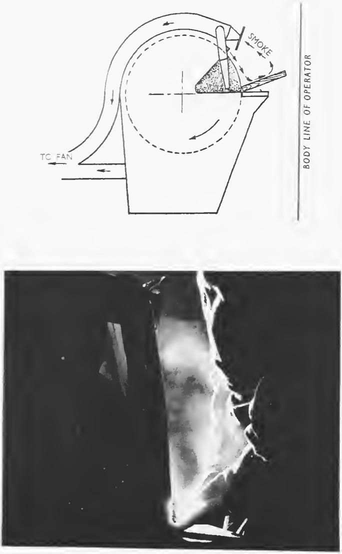
SMOKE
BODY LINE OF OPERATOR
TO FAN

Plate 7. (a) Diagrammatic sketch of the combined exhaust system.
(b) Grinding wood—showing good smoke control.

Photographs by courtesy of The Institute of British Foundrymen.

Plate 8. Combined system with worn 16″ diameter wheel in use. Good dust control in spite of large gap over wheel top.

Photograph by courtesy of The Institute of British Foundrymen

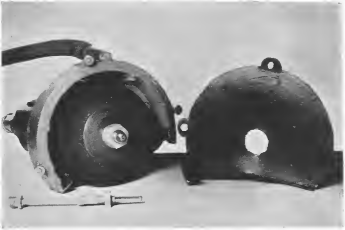

Plate 9. Wheel Hood with Front Plate Removed.

Photograph by courtesy of The Institution of Mechanical Engineers.

Plate 10. Dust control when grinding grey iron with exhaust system operating at 5 inches of mercury. Heavy particles falling—right hand edge of dust cloud under control by the induced air.

Photograph by courtesy of The Institution of Mechanical Engineers.

Plate 11. 8″ diameter bench grinder.

Photograph by courtesy of The Foundry Trade Journal.

Plate 12. Bench Grinder without local exhaust ventilation.
Photograph by courtesy of The British Cast Iron Research Association.

Plate 13. Bench Grinder with new exhaust system fitted and operating.
Photograph by courtesy of The British Cast Iron Research Association

Plate 14. The Portable Surface Grinder.

Photograph by courtesy of The British Cast Iron Research Association.

Plate 15. Grinding without exhaust.

Photograph by courtesy of The British Cast Iron Research Association.

Plate 16. Grinding with new exhaust system fitted and operating.
Photograph by courtesy of The British Cast Iron Research Association

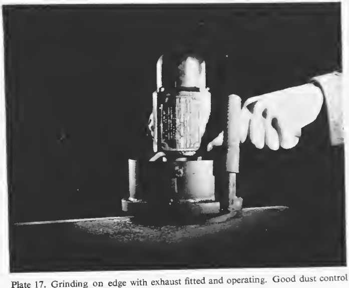

Plate 17. Grinding on edge with exhaust fitted and operating. Good dust control with two point contact.
Photograph by courtesy of The British Cast Iron Research Association.

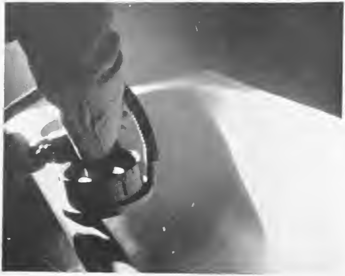

Plate 18. Grinding on edge with new exhaust system fitted and operating. Slight leakage with one point contact.

Photograph by courtesy of The British Cast Iron Research Association

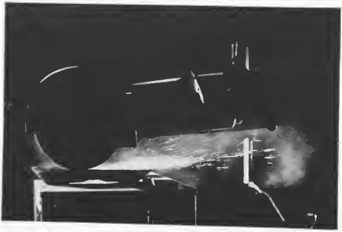

Plate 19. (a) Dust clouds generated when grinding pig iron with a conventional machine.

Photograph by courtesy of The British Steel Castings Research Association

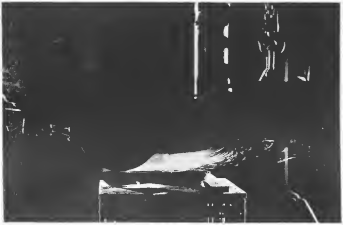

Plate 19. (b) Dust control obtained when grinding the same pig iron with a machine incorporating the B.S.C.R.A. integral exhaust system.

Photograph by courtesy of The British Steel Castings Research Association

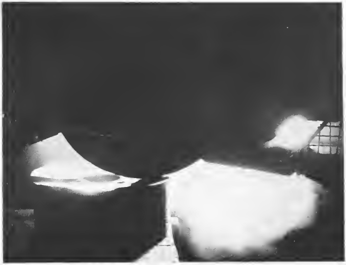

Plate 20. Grinding grey iron without exhaust.

Photograph by courtesy of The British Cast Iron Research Association

Plate 21. Grinding Grey Iron—Dust control with new system operating—leading edge of guard over floor.

Photograph by courtesy of The British Cast Iron Research Association.

Plate 22. Grinding Grey Iron—Dust control with new system operating—trailing edge of guard over floor.

Photograph by courtesy of The British Cast Iron Research Association

Plate 23. Dust control by external duct held over chisel point.
Photograph by courtesy of The Institution of Mechanical Engineers.

Plate 24. Hollow chisel before starting work.
Photograph by courtesy of The Institution of Mechanical Engineers

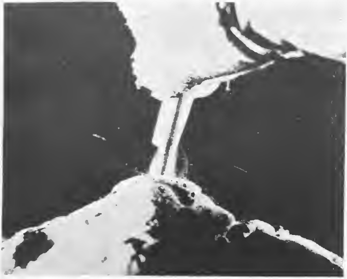

Plate 25. Hollow chisel working on a projection. Exhaust system at a vacuum of 10 inches of mercury.

Photograph by courtesy of The Institution of Mechanical Enginners.

Plate 26. Decoring bar fitted with spray nozzles.

Photograph by courtesy of The British Cast Iron Research Association.

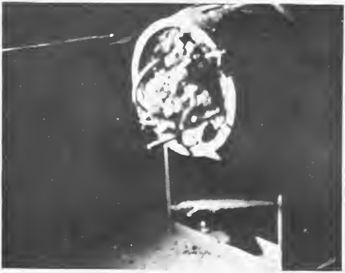

Plate 27. Conditions before starting work. No visible dust in atmosphere.

Photograph by courtesy of The British Cast Iron Research Association.

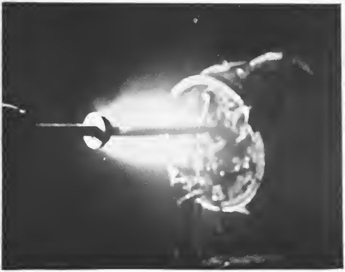

Plate 28. Conditions when decoring wet. No visible dust in atmosphere.

Photograph by courtesy of The British Cast Iron Research Association.

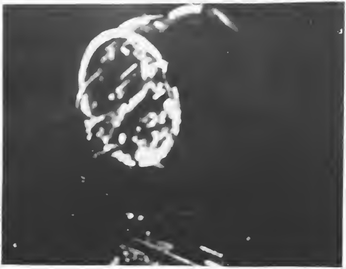

Plate 29. Conditions after finishing wet decoring. No visible dust in atmosphere.
Photograph by courtesy of The British Cast Iron Research Association.

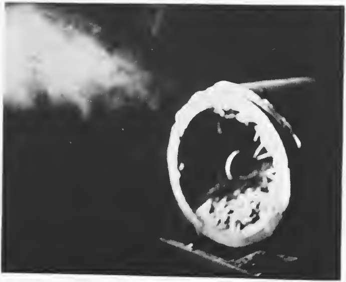

Plate 30. Conditions 2 minutes after finishing dry decoring. Note atmospheric dust cloud.
Photograph by courtesy of The British Cast Iron Research Association.